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MOUND-BUILDING ANTS IN FOREST PLANTATIONS

BY H. B. PEIRSON

State Forest Entomologist, Augusta, Maine[1]

INTRODUCTION

In New England it is a very common occurrence to find colonies of large ant mounds scattered here and there through the woods. Observation will show that these mounds or formicaries almost invariably occur in somewhat sheltered openings or glades in the woods and that regardless of how luxuriant the vegetation may be in the locality, no live trees or shrubs of any height will be found in close proximity to the nests. Furthermore, repeated observations will show that as the nests increase in size so also does the open area around the nests. The writer's attention was first noticeably called to the work of these mound-building ants in the fall of 1919 while making a study of the white pine weevil in pure pine plantations at the Harvard Forest in Petersham, Massachusetts. Wherever the mounds occurred in the plantations the trees soon began to die in an ever widening circle around these nests. These areas of dying trees were found only around the ant mounds so that it seemed very probable that in some way the damage was connected with the presence of the ants. A close inspection showed a deep constriction or lesion on the main stem near the base of the trees. It appeared superficially as though rodents had been feeding on the trunks except for the fact that the bark was in most cases intact. The constriction extended from about three inches above the ground to a distance of about four inches in length entirely encircling the stem. This area had sunken

[1] This study was made while the writer was connected with the Harvard Forest School as investigator in Forest Entomology.

to a depth averaging one-quarter inch and as there was a more or less distinct swelling above the depression it was accentuated even more.

During the winter in going over the literature it was found that similar observations had been made in several locations throughout New England. The damage was laid to a great variation of causes such as bacterial or fungus diseases, loss of roots, etc. In the spring and summer of 1920 considerable time was given over to a comprehensive study of the problem, for it was very apparent that when the nests occurred in plantations the damage amounted to considerable economic importance.

A general survey of the district where the mounds occurred was made and the area was carefully mapped, mounds were measured and areas around the mounds surveyed and mapped. The general location of the mounds made it possible to foretell with a considerable degree of accuracy the probable location of other mounds. The mounds usually occurred in groups on terraces of hill sides where the drainage was good. No nests were found on north exposures. Except in one case the nests were always found on a sandy loan soil. The exception was a colony of about twenty-five nests found on a talus accumulation of disintegrated sandstone. The mounds stand out prominently, located as they are in the center of cleared, more or less circular areas. The size of the mounds varies with the age of the colony. Many nests were three feet in height and over six feet in diameter. The colonies as found in New England often consist of from eight to thirty or more mounds. McCook, who made a study of these ants in Pennsylvannia, found colonies consisting of several hundred mounds, as each of these mounds represents conservatively a family of five thousand ants, some idea of the stupendous number present can be obtained. One colony found by McCook consisted of seventeen hundred mounds some of which were thirty-seven feet in circumference.

In spite of the fact that ants have long been looked upon as an asset to the forest in that they aid materially in destroying insect pests and have even been given credit for distributing forest tree seeds, there is no question but that the damage the mound-building ants do, far offsets their value. Especially is this true in plantations or in areas where natural reproduction is coming up. It is useless to plant in close proximity to the mounds, for the trees are sure to be killed by the ants. Their habits of founding new colonies each

year also make them a decided menace in many localities where forests are not plentiful.

HISTORY AND DISTRIBUTION

The first observations of any great importance in relation to the mound building ants were reported by McCook in 1877 in an exceedingly interesting article entitled "The Mound Making Ants of the Alleghanies." No mention of the damage created by these ants was made in the article, but notes on their life, methods of building the nests, of obtaining food, and social habits were painstakingly made. In 1912, Clinton first reported the dying of trees around the mounds of *Formica exsectoides.* From this date on several foresters, entomologists, and pathologists gave considerable attention to the problem of solving the reason for the death of youg pine near the nests. All of the observers noted a fungus growth that was almost invariably present, but experiments in innoculation of healthy trees with the fungus did not produce the characteristic lesions, so that none of the writers felt certain as to the cause. Hawley and Record (1916) made the statement that the range of species attacked seemed too great for a single fungus disease. Later investigators succeeded in isolating nine distinct fungi, and there were others that were not identified.

The distribution of *Formica exsectoides* seems to be restricted largely to Northeastern United States, probably following the sand belt. Specificially it is reported as occurring in Virginia, Pennsylvania, New Jersey, Massachusetts, and Maine. Muckermann reports its occurrence in Southwestern Wisconsin, and Forel mentions its occurrence in lower Michigan. A variety of exsectoides—*Formica exsectoides opaciventris*—occurs in Colorado. *Formica exsectoides* is the only species in eastern North America which regularly makes large conical cones in the forest. A closely related species, *F. rufa,* occurs in Central Europe.

NATURE OF DAMAGE

1. *White Pine*

In order to determine the reason for the death of pine trees around the nests, dead trees were cut down and carefully examined. In every case a characteristic lesion was found near the base of the tree on the main stem. This lesion takes the form of a deep constriction, the sunken area completely girdling the tree and usually extending on the

main stem for a distance of about four inches. Both above and below this lesion there was a distinct swelling which denoted that the flow of the sap was interfered with. In some cases small adventitious suckers, or roots, were sent out from above the lesion in an apparent effort to bridge over the gap. An examination of the lesion itself gave the impression that the cells had collapsed. The reddish sunken areas seem to center around the lenticels, and becoming confluent, form the major lesion. In nearly all cases a fungus growth was found on the diseased area, which upon identification proved to be a species of Phoma. Other investigators have isolated nine distinct fungi, mainly species of Fusicoccum. Although repeated efforts were made to reinfect healthy trees with the fungi, no success was obtained. It was thought possible that the roots might be affected, as some of the writers had suggested that the ants might possibly chew off the roots. The author was, however, unable to find any signs of roots damage. Superficially the dead trees give the appearance of having been killed by drought. Areas mapped showed that trees may be killed at a distance of thirty feet from the nest. The circle of dead trees around the nest widens each year.

No indisputable reason for the killing of the trees has so far been advanced. From observations made at Petersham it appears, however, as if the ants killed the trees in an effort to keep the nests continually in the sunlight. In mapping the areas of dead trees around the nests it was noticeable that the greatest damage was east, south, and west, and that as soon as the shadow from a tree was cast on the nest for any length of time, that tree was attacked. It is only natural that as the nests increase in size the open area around them should be yearly enlarged. Correlated with this, the yearly growth of the pines causes the trees further and further from the nest to cast ever lengthening shadows. White pine above six feet in height is rarely killed.

2. *Hardwoods*

Another and entirely different type of damage is found in the case of hardwoods occurring in close proximity to the nest. The ants are apparently unable to kill the trees in the same manner that white pine is killed and necessity has forced them to adopt other tactics. In the case of poplar (*Populus tremuloides*), lesions were formed on one side of the small trees near the base, which weakened them enough so that they were broken over by wind. In the case of apple and sumac, the

ants were observed defoliating the trees by chewing off the petioles. In the case of a small scrubby wild apple tree growing near one nest, the ants showed a decided sense of discretion. The foliage on one branch in particular cast a shadow on the nest. The ants in some unknown way were apparently able to tell just which branch was causing the trouble, for their efforts were almost entirely confined to nibbling off the foliage from this particular branch, and inside of a week had almost completely defoliated it. Some attention was also given to the foliage on other branches, but it almost appeared as if they realized that it was a hopeless job to remove the foliage from the entire tree. In most localities even the grass and low bush blueberries and other small plants and shrubs are killed for a distance of several feet around the mounds.

There seems to be no limit to the species of trees killed or severely injured. Those noted are *Pinus strobus, Pinus sylvestris, Juniperus communis, Juniperus virginiana, Populus tremuloides, Hicoria ovata, Betula populifolia, Quercus ilicifolia, Pyrus malus,* and *Rhus hinta.*

HABITS AND LIFE HISTORY

The mounds or formicaries usually occur in groups fairly close together, and their size is a fairly accurate index to their age. The mature or completed mound is usually from two and one-half to three feet in height and approximates six feet in diameter. When one considers that the earth used in building these mounds is the result of countless tunnels in the ground, most of which are no larger in diameter than the size of an ordinary lead pencil, some idea of the great extent of these galleries can be obtained. Examinations showed that in some cases the tunnels extended twenty or more feet from the nests and penetrated to a depth of six feet. The mounds are built largely of coarse sand supported somewhat by pieces of straw, small twigs, etc. It has been estimated that from one to four cubic feet are added to these mounds each year. The mounds in a group are usually connected with each other by tunnels. One of these mounds might well be termed the mother colony from which subsidiary mounds are built as the colony increases in size.

The openings to the nest are almost invariably found around the base of the periphery, those seen on the sides or tops are merely the places at which the internal galleries are being constructed. These galleries are constructed following and during rain storms in the form

of long tents, the ants later filling in around these galleries with dry soil. The material for these mounds comes from the underground tunnels and chambers in which the ants spend the winter. The object of these mounds is generally conceded to be for incubation purposes. The mounds act as compost heaps, and due to the slope of the sides absorb a great deal of solar heat. It is interesting to note that the longest slope is usually to the south or west. During the breeding season the eggs and pupae are brought up into the mound from the underground galleries as soon as the sun begins to shine on the mounds and kept there until the sunlight ceases to strike the nest. All vegetation is kept off from the active mounds by the ants, probably as this becomes an obstacle to their coming and going. Plant growth on the nest would also prevent the sunlight striking the mound and would have a tendency to keep the nest damp by preventing evaporation. Long galleries extend out from the nest to the feeding grounds, particularly to trees on which colonies of aphids are being tended. The openings of some of these galleries become the center of operations for new mounds. Such galleries have been found sixty feet from the nest. During the fall the nests were covered with dried leaves which undoubtedly aid in keeping the temperature of the nest up, and prevent damage by washing from the fall rains. In the vicinity of Petersham, Mass., *Myrica* was most commonly used.

The life history of *Formica exsectoides* is not fully known and notes made by the author are by no means complete. There appears to be no stereotyped life history, but eggs are laid throughout the warm season so that no definite data can be obtained by studying the life history in the field. It is necessary to rear them in artificial nests in order to determine the length of the different stages. In general, large number of queens and kings swarm at the same time, mating taking place during the nuptial flight. The kings die soon after the flight. The queens alighting, if fortunate, are seized by workers who immediately start to build a new nest and tend to her wants. She immediately breaks off her wings with her hind feet, apparently realizing that her wings are only an inconvenience from this time on. Large numbers of very small white eggs are laid. These are carefully tended by the workers and kept where it is warm, being constantly changed from place to place in the nest during the day. The length of the egg stage is doubtful, but probably does not last over two weeks. The larvae upon hatching are first fed by

the queen and as they become older are fed by the workers. The mature larvae spin yellowish white, silken, papery cocoons. Within these cocoons the larvae change to the adult ant. This transformation takes approximately two weeks, although there was quite a variation in the period required for this change to take place in the case of larvae kept in artificial nests. There are apparently several generations during the year. It has been found that queens of certain species may live for fifteen years (the longest life known in the insect world), repeatedly rearing new families. The workers have been found to live for several years. Some of the fruitful queens are seized by the workers upon the mounds or in close proximity to them and are forced back into the nest. The great majority are apparently lost and either die of starvation or are captured by other insects or by birds. Two years observations including extensive surveys showed that very few new colonies are founded each year, and most of these were within a quarter of a mile of the mother colony, in spite of the fact that large numbers of queens were seen.

It can readily be understood that a colony of ants containing anywhere up to two hundred million, or in some cases even four hundred million individuals, must require a large amount of food. It has been estimated by Forel that 100,000 dead insects are daily brought into a single nest during the most active season. If even a reasonably small percentage of this number were daily brought in, the number would still be stupendous. All types of insects including beetles, flies, moths, grubs, and caterpillars are captured and dragged into the nests. Honey dew, secreted by aphids, appears to be the most staple food. It was of rare occurrence that large colonies of aphids tended by the ants were not found in close proximity to the nests. Ants have been shown to use considerable discretion in their choice of food, for when poison has been mixed with edible food the ants separate the two, putting the poison in a pile to one side.

METHOD OF KILLING TREES

It was quite apparent that the fungi alone found on the lesions could not have caused the death of the trees. Knowing that these ants used formic acid in combating insect enemies, it seemed possible that they might also use it in the destruction of trees. A large number of ants were collected and the formic acid extracted in a water solution. This was then injected into the main stem at the base of several healthy

pines and within a week a lesion identical with that found at the base of dead trees around the nests appeared. The evidence was so conclusive that no doubt remained as to the way in which the ants destroyed the trees. The writer was fortunate enough to be stationed in Amherst, Mass., during the winter at the State College where excellent equipment was made available to further carry on work in relation to the problem. White and red pines, three-year transplants, were obtained from the State Nursery. These were potted and kept in the greenhouse. Commercial formic acid, sp. gr. 1.060, was used in the experiment. This acid was apparently not as strong as that obtained from the ants, but was the best available.

Several methods were used in applying the acid to the seedlings. In some cases a large number of needle-like punctures piercing into the phloem were made in the bark, and absorbent cotton saturated with the acid wrapped around the main stem. In other cases the acid was injected directly into the stem. A third method tried was merely to wrap saturated absorbent cotton around the main stem. This cotton was then partially covered with paraffine to prevent too rapid evaporation, as the acid is very volatile. After leaving the treated seedlings for from one to three weeks, microtome sections were made and these were stained and mounted on permanent slides. Several very important changes were noticeable in comparing the treated material with untreated sections. In the first place the resin tubes or ducts were abnormally swollen, even in some cases to the bursting point, forming a typical emphysema. The relatively large cells in the primary cortex had collapsed, as was also true of the cells of the phloem.

The chemical action of the acid on the cell contents could not very well be noted, for in preparing the sections for staining it was necessary to run them through alcohol, which coagulates the protoplasm within the cells. Knowing in a general way the contents of the cells, it was possible to make studies of the action that would be liable to take place without depending entirely upon the use of white pine. Sections of Spirogyra were obtained and temporary waterslides were made. While watching these slides under the microscope, a small amount of formic acid was placed on the slide. The subsequent reaction was most interesting. Owing to the extremely large size of the cells of spirogyra it was easy to note what was taking place within them. Almost as soon as the acid was added, the protoplasm within the cell began to coagulate and in a comparatively short time had formed in a

mass at the ends and on the sides of the cells. This then was what took place within the minute cell of the white pine. From a study of the structure of the white pine stem and the function of the various cells a clearer idea of the way in which the acid acted was obtained. For example, beneath the cortex and phloem are a series of cells known as the "sieve tubes" through which the organized food is conducted. Over the so-called "sieves" on the sides of the sieve tubes is a thin layer of protoplasm which when acted upon the formic acid would coagulate, stop up the sieve and thus present the conduction of the food. In the stained sections it was apparent that the cells had been killed or destroyed down to the xylem or wood parenchyma. The action of the acid on the white of an egg, which is nearly pure protoplasm, gave the same results as were noted within the cells of Spirogyra, that is, the white of the egg became coagulated. No action resulted from treating starch with formic acid, it proving to be insoluble. Proteids are coagulated by the acid.

Formic acid is a colorless, mobile, vesicatory liquid of penetrating odor not unlike acetic acid. Stinging is very common in nature, being secreted by both plants and animals. Stinging hairs of nettles contain the acid which causes the first sensation of burning, although the resulting inflammation is probably due to enzymes which act as poisons. Formic acid is also secreted along with other acids in pitcher plants. The acid has been found in the leaves, bark and wood of the Coniferae and several tropical plants. It occurs in certain caterpillars such as *Bombyx processionea,* and *Cerura dicranura* the secretions ot which contain 3.75 per cent of the acid. The acid is also found in various secretions of the body such as the blood, sweat, etc. It is also produced by microbic action. Owing to its power as a reducing agent it seems probable that the swelling of the resin ducts is due to the formation of carbon monoxide. Commercially the acid is made by distilling oxalic acid with glycerine.

It was not until the folowing spring that the ants were actually observed attacking the pine and then only after days of waiting Climbing the main stem the ants begin to chew and tear away at the epidermis and the cork cambium surrounding the lenticels, meanwhile squirting acid into the wound. The acid penetrating into the trunk coagulating the principal cell contents causes a complete cessation of the downward flow of the sap thus killing the tree. This accounts for the notable swelling above the lesion. It is patent that a large number

of these small lesions combined to make one completely girdling the trunk, will soon destroy the tree. The immunity of the larger trees is due primarily to the thick rough bark through which the acid will not readily penetrate.

CONTROL

Ants are very resistant to adverse conditions and are extremely difficult to kill. Even strong poisons such as potassium cyanide, corrosive sublimate, or carbolic acid are not very effective in destroying them. Submergence in water, lack of food and extremes of temperature are withstood most remarkably. The tenacity with which they cling to their nesting sites has been remarked upon by many writers. Owing to their enormous fertility and the fact that the queens spend most of their lives in the inaccessible penetralia of their nests some idea of the difficulty to be encountered in destroying a colony can be seen. It is paramount that the queens be destroyed in order to get rid of the nest, for regardless of how many thousands of the workers may be killed if the queens are left alive the colony will be revived by these mothers. It is essential then that a poison in order to be effective must penetrate deep into the underground galleries.

Hydrocyanic acid gas is apparently of no use, due to the fact that it is lighter than air. Kerosene and gasoline kill only to a depth of approximately one foot, and are therefore useless. Napthalene was tried, but apparently had no effect upon the ants other than irritating them.

The only effective means of control found was fumigation of the nests with carbon bisulfid. This gave very satisfactory results and can be highly recommended. There are several ways in which the fumigating can be carried on all of which give reasonably good results. The following method tends to lessen the amount of the carbon bisulfid used, and also aids in making more effective the amount that is used.

The materials necessary for the fumigations of each nest are, a shallow pan or dish capable of holding one pint of the carbon bisulfid, a large wash tub or dish pan, and the fumigant. First a small pile of dirt or sods should be placed handy to the mount. From one to one and one-half pounds of the carbon bisulfid, depending upon the size of the nest, is then poured into the shallow pan or dish, and placed on top of the mound. A few holes are then quickly punched with a

stick in the nest and the large pan or tub placed bottom up over the mound. The pile of dirt and sods is then thrown around the base of the large pan covering any part of the mound left exposed by it, and packed down. This prevents the escape of the gas and also aids materially in keeping the ants in the nest. It is best to leave the pan over the nest for from six to eight hours, depending, of course, upon the amount of the fumigant used.

Carbon bisulfid is a colorless liquid with an extremely disagreeable odor, especially if impurities are present. It is highly explosive and should be kept away from fire. The liquid is very volatile, forming a colorless gas 2.68 times as heavy as air. Too much emphasis can not be laid upon its explosive dangers. It can be obtained in one-pound cans from nearly any druggist, or in larger lots from chemical concerns. The prices on 50-pound cans vary from 10 to 15 cents per pound. Smaller lots cost slightly more, and there is a corresponding reduction in the 100 and 500 pound cans.

Control by Disease

The writer believes that very interesting and satisfactory results can be obtained by infecting a colony with a bacterial disease. Owing to their social, or gregarious habits, and the fact that the ants feed each other, a virulent disease should spread very rapidly. Control would also be made much more economical.

Bacillus acridiorum has been used with a great deal of success in the control of several insect pests. Birds and mammals in general are immune to this bacillus, one notable exception being the sewer rat which dies from generalized septicema a few hours after injection, although apparently immune to cultures ingested. According to Marshall [2], a species of small ant near Paris was annihilated in 1911 by *B. acridiorum.* In a like manner a species of ant near Buenos Aires was completely destroyed by placing a few drops of the culture on each hill. *Atta sexdens,* a tropical and sub-tropical pest, was annihilated at Chaco and Tucuman after the virulence had been increased for this species of ant by many passages.

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[2] Miscrobiology. Charles E. Marshall, Amherst, Mass., 1912, pp. 637-643.

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RAY VOLUMES OF THE COMMERCIAL WOODS OF THE UNITED STATES AND THEIR SIGNIFICANCE[1]

By J. E. Myer

In the scientific study of matter it is customary to consider the problem from many angles and to subject the material to an ultimate analysis. That this may be accomplished, each element or structure is examined separately or in the aggregate in order to determine its influence upon the character and properties of the substance as a whole. This method of intensive investigation, when applied to the component elements of steel, has shown conclusively that minor modifications do have very important effects upon the qualities of the final product. Since such differences in composition have a direct bearing upon the reactions of a more or less homogeneous substance, does it not seem feasible that the much greater variations in the anatomical structures of wood might bear an even more intimate relationship to its reactions? With this idea in mind the writer, at the suggestion of Dr. H. P. Brown, has made a careful survey of the medullary or wood rays of the commercial timber species which are indigenous to the United States.

The results of previously published researches dealing with numerical and volumetric studies of wood rays have already been enumerated by DeSmidt (*1*) in his observations on the ray content of slippery elm (*Ulmus fulva* Michx.), and consequently no further reference to the general problem is necessary. It is the object of this paper, therefore, to show the relation which exists between variations in ray volume in different species and their physical properties, inheritance, and the conditions under which they have grown.

The methods employed in calculating ray volume were developed in part in this laboratory and consequently should receive some attention. Previous investigation has shown that woods vary thus not only as between species, but also between different individuals in the same species, and in different parts of the same tree. Such discrepancies are due to inherited factors in the meristem such, for example, as those which predetermine that white oak shall have compound and uniseriate

[1] A thesis submitted for the degree of Master of Science in the Department of Wood Technology, New York State College of Forestry.

rays or that birch shall have diffuse storage tissue. Differences in the ecology of growth does exert an influence on ray volume. Although inheritance plays an important rôle in limiting the volume of rays in different woods, it is not as effectual as environment on individual variations. In reference to the latter it is well known that such factors as site, rate of growth, habitat and the like may have no small influence on the development of cells for the storage of food, but as DeSmidt (*1*) has shown such variations are least marked in the merchantable part of a tree, that is, the bole, and consequently all material was selected from logs or lumber, thus obviating as much as was possible the necessity for careful data as to growth conditions.

The volume of the rays in the different woods was determined by the following method: Tangential sections of each specimen were prepared in the usual way, and photomicrographic negatives magnified 100 diameters were taken directly onto 8 to 10 inch bromide paper. This process gave an exact representation of the tangential surface of the rays which could then be cut from the photograph and weighed, and their weight was then compared with weight of the total area of a definite portion of the print. In this way it was possible to secure the percentage of ray area in a tangential section, or the proportion existing between ray area, and the area of other tissues.

Consequently, since rays are continuous and vary but little in size as they extend in a radial direction, the volume of a block may be considered as a series of tangential sections in which the ray numbers and consequently area remains fairly constant. It follows, therefore, that the rays of any cut are reasonably representative of all the sections and, from this, it may be assumed that the ray area of the tangential section per unit area varies directly as ray volume per unit volume, which may be indicated by the following formula:

Ray area : total area = ray volume : total volume.

At the start it must be conceded that the study, which follows is based on the premise that rays vary little in size throughout the merchantable part of a tree, a condition which holds true in general as is pointed out elsewhere in this paper. To be sure, new rays appear in repsonse to necessity as the tree increases in girth, but the number per unit area remains nearly constant or changes little since the production of new rays, but keeps pace with the increasing periphery; and in consequence tangential surfaces show a surprising uniformity in the amount of such

storage tissue. Of course, variations occur which must be ascribed to individual diversity and to changes in volume within the ring,[2] but this type of variation has been nullified by taking three representative sections of each species.

When the material had been collected from the different sources, when the proper care had been taken to procure the most representative sections and when the best method of determining the ray content had been chosen, it was found that variations within a species were usually not over 4 or 5 per cent, as shown in Table 1. The greatest deviations were found in the beech, black gum, and box elder where the rays are either large or numerous, reaching a maximum of 11.8 per cent in the last named species. In the soft woods the deviation was less marked, and in but two species of the thirty-eight was the deviation greater than 4 per cent.

TABLE 1.—*Ray Content of the Commercial Woods of the United States.*

Softwoods	*Average*	*Variations in specimens*
Pinus strobus Linn	5.39	.4
Pinus monticola Dougl	6.59	2.6
Pinus lambertiana Dougl	5.70	.7
Pinus resinosa Ait	7.00	1.4
Pinus ponderosa Laws	6.78	2.4
Pinus jeffreyi "Oreg. Com."	8.1	...
Pinus murrayana "Oreg. Com."	5.70	.9
Pinus taeda Linn	7.63	1.6
Pinus rigida Mill	7.25	2.7
Pinus virginiana Mill	7.22	.9
Pinus echinata Mill	8.05	3.3
Pinus divaricata Ait	8.10	2.0
Pinus palustris Mill	8.30	3.7
Pinus heterophylla Sudworth	11.7	1.8
Larix laricina Koch	11.07	4.2
Larix occidentalis Nutt	10.0	1.1
Picea rubens Sargent	4.98	2.7
Picea canadensis B. S. P	7.09	.4
Picea engelmanni Engelm	5.91	2.5
Picea sitchensis Trautv. and Mayer	7.27	3.1
Tsuga canadensis Carr	5.96	.7
Tsuga heterophylla Sargent	8.80	4.0
Pseudotsuga taxifolia Britt	7.37	2.1

[2] The volume of any ray is least on the transitional zone between spring and summer wood, and greatest at the end of the annual ring. (*1*).

TABLE 1.—*Ray Content of the Commercial Woods of the United States.* (Continued.)

Softwoods	*Average*	*Variations in specimens*
Abies balsamea Mill	5.68	2.3
Abies lasiocarpa Nutt	5.07	1.8
Abies grandis Lindl	6.68	5.2
Abies concolor Parry	9.48	1.8
Abies amabilis Forb	6.68	1.5
Abies nobilis Lindl	6.57	2.1
Taxodium distichum Rich	6.62	2.6
Sequoia sempervirens Endl	7.85	2.5
Libocedrus decurrens Torr	8.90	.9
Thuja occidentalis Linn	3.43	.6
Thuja plicata Don	6.93	1.4
Chamaecyparis thyoides B. S. P	5.18	2.4
Chamaecyparis lawsoniana Parl	5.57	1.7
Juniperus virginiana Linn	6.26	1.3
Juniperus occidentalis Hook	6.8	.9
Average	7.8	2.0

Hardwoods	*Average*	*Variations in specimens*
Juglans cinerea Linn	8.68	2.0
Juglans nigra Linn	16.83	3.7
Hicoria pecan Britt	26.35	2.7
Hicoria minima Britt	16.8	7.8
Hicoria ovata Britt	19.97	9.4
Hicoria glabra Britt	23.4	7.0
Salix nigra Marsh	10.6	7.0
Populus tremuloides Michx	9.63	4.4
Populus grandidentata Michx	11.07	5.6
Populus deltoides Marsh	13.7	5.8
Betula populifolia Marsh	9.32	2.2
Betula papyrifera Marsh	11.07	5.6
Betula nigra Linn	15.83	3.3
Betula lutea Michs	10.77	.9
Betula lenta Linn	16.60	6.4
Fagus atropunicea Sudworth	20.43	5.3
Castaneo dentata Borkh	11.9	3.3
Quercus alba Linn	27.96	....
Quercus prinus Linn	25.3	....
Quercus acuminata Houba	21.9	....
Quercus platanoides Sud	29.72	....

TABLE 1.—*Ray Content of the Commercial Woods of the United States.* (Continued.)

Hardwoods	*Average*	*Variations in specimens*
Quercus virgianiana Mill	32.2	....
Quercus rubra Linn	21.26	....
Quercus velutina Lam	31.36	....
Quercus digitata Sud	18.80	....
Quercus nigra Linn	28.30	....
Quercus densiflora Hook and Arn	42.26	....
Ulmus pubescens Walt	13.03	4.2
Ulmus americana Linn	11.43	7.2
Ulmus racemosa Thomas	11.7	3.5
Ulmus alata Michx	18.6	3.8
Celtis occidentalis Linn	13.3	3.0
Celtis mississippiensis Boss	....	....
Magnolia acuminata Linn	13.87	3.5
Liriodendron tulipifera Linn	14.22	2.5
Liquidambar styraciflua Linn	18.3	1.8
Platanus occidentalis Linn	19.2	3.7
Prunus serotina Ehrh	17.2	3.4
Gleditsia triacanthos Linn	18.46	3.3
Robinia pseudoacacia Linn	20.93	3.1
Acer macrophyllum Pursh	18.46	3.8
Acer saccharum Marsh	17.93	5.2
Acer saccharinum Linn	11.93	5.0
Acer rumrum Linn	13.3	2.2
Acer negundo Linn	16.19	11.8
Tilia americana Linn	6.08	3.8
Tilia heterophylla Vent	5.3	2.0
Nyssa sulvatica Marsh	17.63	9.7
Fraxinus quadrangulata Michx	17.1	6.1
Fraxinus nigra Marsh	12.03	7.1
Fraxinus americana Linn	11.9	4.9
Fraxinus oregona Nutt	14.50	4.4
Catalpa catalpa Karst	9.20	11.1
Catalpa speciosa Warder	13.3	2.4
Average	17.04	4.7

In addition to minor variations due to individuality within a species, there are major inequalities between species which are predestined by inheritance and which, for example, determine that basswood shall have

narrow diffuse rays with a correspondingly low volume, or that the oak shall possess compound rays with a large storage system. Still other fluctuations are owing to conditions of growth, botannical features, and the quality of the wood. Differences in the soil apparently have a limited influence only as they produce other modifications such as those which inhibit growth and the like and which may, in their turn, produce alterations in the ray volume. On the other hand, if the substrata in two stations show wide differences, such a discrepancy in the storage system may be manifest as shown by Geiger (*3*) in relation to teak where a specimen grown on a rich, deep soil showed an increase over one inhabitating a poorer site. Among the woods listed in this paper, however, no such relationship was evident.

That topography may produce modifications in the storage system is evident in species grown in swamps and on high ground. It has been shown in this laboratory that lowland forms of ash, tulip poplar, and bald cypress showed a marked increase in ray volume over other representatives grown at higher elevations. In contrast to the increase typical of swamps it would appear that species growing on high mountains have a tendency to reduce the amount of tissue reserved for storage. This may be due in part to a greater tendency to retain the leaves, and for a greater economy of effort owing to an abbreviated growing season, and a cold climate, a characteristic which, as material becomes available, may appear in southern and northern representatives of the same species as in the case of the alder (*2*).

The writer's calculations also show that the semi-tropical live oak (*Quercus virginiana*) and the tanbark oak (*Quercus densiflora*) contain a higher percentage of ray tissue than any of the more northern oaks as indicated in Table 1. This augmentation of the storage system becomes even more striking when it is associated with the evergreen habit of both species which would tend to produce an opposite result. Apparently the tendency toward an increase in warmer localities and a decrease in colder stations is owing to the progressive brevity of the growing season as the northern limit is approached with its ever increasing need for economy in food production.

The relationship of a tree to its neighbors is also influential in producing modifications in the ray content. If a tree is suppressed, decreased photosynthesis is manifest in a reduction of the tissue reserved for storage, and in the same way dominance with its concomitant solar activity is responsible for an increased food-retaining system. This

has been shown by Hartig (*4*) where a suppressed red oak showed only 4 per cent of broad rays in the wood laid down during this period, but when released from such an adverse condition by the removal of the surrounding trees the per cent increased from 10 to 12 per cent.

Doubtless all of these environmental factors produce changes only as they influence food manufacture, and, provided the elaborated carbohydrates are far in excess of the immediate needs of the tree, a larger storehouse must be provided for their retention. If, however, the tree must endure a poor site, impoverished soil, or an abbreviated growing period the corresponding reduction in the synthesis of food will manifest itself in a reduced ray content. Thus it would seem that variations within a species are largely the result of diverse ecological conditions.

In addition to these variations within a species which are due to environment, there are other features which produce not intra-specific but inter-specific modifications. As has already been suggested, the greatest variations may be traceable to inherited factors which predetermine the types of rays as well as the volume within limits which may appear. To be sure, this phase of the problem is applicable to variations within species only to a very limited extent, if at all, but cannot be disregarded in any discussion of the relative ray content between species, genera, and families. A reference to the table will show that the soft woods with their characteristic uniseriate rays have an average volume of 7.08 per cent with extremes of 3.4 per cent in *Thuja occidentalis* and 11.7 per cent in *Pinus heterophylla*.[3] There seems to be no correlation between genera and the amount of ray tissue which can not at least in part be ascribed to other causes, since all genera of the Pinaceae approach the average of 7.08 per cent with the cedars slightly below, a fact which may be due to their generally northern range and lack of resin canals. The larches, the only deciduous northern conifers in this country, show the highest ray average; a fact which may be considered as a manifestation of their deciduous character. Within a genus wider variations may occur among the several species. The genus *Pinus*, for example, with its large number of representatives and wide diversity of characters, site, and geographical distribution naturally shows the widest variation. The hardwoods with their several types of rays show wide fluctuations in this respect, but fail to exhibit any diversity which can not be discussed briefly and in

[3] It will be observed that these two species are representative of the North and South, respectively, and consequently the gap may owe its width at least in part to the difference in the length of the growing season.

a very general way. The average of all the hardwoods studied was 17.04 per cent with a maximum in *Quercus* and a minimum in *Tilia.* The studies still further prove that the measure for any species within a genus can only in the most general way be considered as representative of the genus or the family to which it belongs.

It may now be advisable to discuss ray volume in relation to various structural features with which it is associated. The climatic changes during past geological ages which resulted in the periodic loss of leaves, naturally produced profound alterations in the anatomy of those species where such a habit was assumed. Persistent leaves act as storehouses during a resting period, and consequently obviate the necessity for the elaboration of such a system in the wood. This phase of the problem dealing with the evergreen habit must naturally be confined to the conifers since but two of the oaks considered have persistent foliage and have, for climatic reasons, been shown to possess a high ray volume. In the same way the difference of 10 per cent between the soft and hardwoods may be due in part at least to leaf abscission. A like reduction of ray volume in evergreen hardwoods has been mentioned by Simon (7) who states that the deciduous blueberry (*Vaccinium myrtillus* L.) possesses a higher ray volume than the cowberry (*Vaccinium vitis-idaea* L.) and that the evergreen Mahonia (*Mahonia aquifolium* Pursh.) has a lower volume than the deciduous barberry (*Berberis vulgaris* L.)

As far as could be observed other external features appear to have no appreciable influence on the volume of the storage tissue and consequently the anatomical characters of the wood may now be considered. The various types of rays are of the utmost importance, and will be discussed separately. The uniseriate type, characteristic of the soft woods, showed an average of 6.76 per cent with extremes of 3.43 per cent in *Thuja occidentalis* and 9.48 per cent in *Abies concolor.* Those woods possessing fusiform rays of greater size, owing to the inclusion of a horizontal resin canal, show an average gain of only 0.62 per cent over those woods where such structures are absent. Only three genera of hardwoods, the willows, poplars, and chestnut, possess uniseriate rays alone and the average volume per cent was 10.67 per cent with a maximum divergence of 6 per cent between the extremes. It is of interest to note that the deciduous larch also with uniseriate rays has an average volume of 10.5 per cent or only 0.13 per cent below that of the deciduous hardwoods with a like storage system.

The diffuse rays with their wide distribution among hardwoods naturally show greater variations and a larger average as might be expected from their multiseriate character. The average of the thirty-six species and the three sections from each species show 14.13 per cent reserved for storage with a minimum in the basswood of 5.3 per cent and a maximum in the southern *Hicoria pecan* of 26.35 per cent. The exceptionally large compound rays show the largest average of 28.08 per cent with a maximum of 42.26 per cent in the tanbark oak, and a minimum of 20.43 per cent in *Fagus atropunicea.*

Up to this point the rays alone of all the different tissues have been considered and consequently it may be well to show their volumetric relation to other structural features. Since the coniferous and dicotyledonous species may also be separated on the presence or absence of vessels in the wood it naturally follows that the non-porous species with their uniseriate and fusiform rays will show a lower content than the more adaptable hardwoods with their broader storage bands. It is doubtful, however, if the difference of 10 per cent in the average between the two categories can be ascribed to a change in the transportation system, but rather to the deciduous character and greater leaf surface of the latter, both of which have made necessary and possible an increased food development and storage system as well as more specialized conducting tissue. Thus in the *Pinaceae* absence of vessels as well as a low ray content is the result of and not the cause of a small leaf area and an evergreen habit. In the same way the converse is true of the hardwoods where an expanded photosynthetic mechanism and a periodic loss of foliage has called into being specialized conduction cells and broad rays.

It would naturally appear that the amount of vertical parenchyma in a wood have a decided influence on ray volume, since a large number of such storage cells could act in harmony with the ray storage tissue and divide the labor of conserving elaborated food materials, thus producing a diminished ray content. However, careful studies show no such relation, and it must be assumed that the presence or absence of vertical storage cells does not appreciably influence the volume of the rays.

In a similar way there seems to be only a slight relation between ray volume and the distribution of vessels into ring and diffuse porous types. The average was slightly greater for ring porous woods.

It now remains to be shown that there is a quite definite relation between ray volume and the physical and mechanical properties of

the species listed. It is but natural that the physical properties should show a wide degree of divergence not only between different species, but also between various specimens of the same wood since they are dependent upon all the anatomical modifications due to inheritance or ecological conditions of growth and will naturally reflect an alteration in any of the tissues.

Any text on the physical properties [4] of timber will stress the importance of specific gravity, that outward manifestation of the whole internal organization, as the most reliable indicator of the way in which a wood will react under an applied force. A study of the tables and strength values for the different species show that the measure of weight and density is directly proportional to an increase in ray volume. The greatest maximum divergence was shown by *Thuja occidentalis* where a specific gravity of 0.32 was associated with a ray volume of 3.43 per cent and the minimum by *Libocedens decurrens* where the figures are 0.36 and 8.9 per cent, respectively. In the hardwoods the larger variations in the anatomy produced still greater departures from the mean. In this case the basswood was associated with a specific gravity of 0.40 and a ray volume of 6.8 per cent, while the minimum was represented by *Platanus occidentalis* with 0.54 and 19.20 per cent. When these terminal points are compared with the averages for all it will be seen that the divergence is not as great as might be anticipated from the extreme structural variations within the different species.

Closely associated with specific gravity is that quality inherent in wood known as hardness, or the resistance offered by all the elements to indentation or abrasion. As in the first case, a proportional increase in the numerical measure of hardness appears to follow closely an increase in ray volume. In the soft woods there is for each increase of one per cent of ray volume and increase resistance to indentation of 5 pounds per square inch, and in the hardwoods a similar gain for each unit added to the volume of storage tissue. This increase in hardness is naturally due only in a small degree to the augmented ray tissue. but rather to the thickening of the walls of all the elements which appears to be associated with it.

The idea that the modulus of rupture, the measure of the breaking strength of a wood, is in general proportional to specific gravity is

[4] The strength values have been taken from results obtained at the Forest Products Laboratory at Madison, Wisconsin, and published in U. S. Department of Agriculture Bulletin 556.

well established. That it is also proportional to an increase in ray volume is surprising since such tissue composed as it is of cells running perpendicular to the axis of the strengthening elements, would at first glance suggest an opposition correlation. Apparently, however, the tendency for the storage cell walls to be thin is compensated by a greater number of their units in contrast to fibers and vessels so that there is little if any reduction in the solid volume of the tissue, due to fluctuations in the proportion of vertical and horizontal elements.

The greatest difference in the relation of ray content to strength values was shown in the compression parallel to the grain. This does not mean, however, that there was no increase concomitant with an augmentation of the storage systems, but that it did not keep pace with the other mechanical data. In all probability such a lack of progress is owing to the reaction of the rays themselves to an applied pressure, since the rays running as they do at right angles to the fibers create a zone of weakness at their points of union with vertical cells and between the individual cells of the rays.

The numerical data to which allusion has just been made, shows that compression perpendicular to the grain progresses in direct proportion to the increase in ray volume, while compression parallel to the grain shows a proportional increase only half as great when correlated with a similar gain in storage tissue in the different species of hardwoods. The strength values also show that the conifers are from 7 to 9 times as resistant to a crushing force applied parallel to the grains as it is perpendicular to the long axis, and there appears to be no correlation between an increase in ray volume and a lessening of the divergence between end and side compression. This fact is doubtless due to a generally small variation in the amount of storage tissue owing to the presence of small rays and a more or less simple and uniform organization. In the hardwoods, on the contrary, those possessing the lowest per cent of ray volume have a tendency to resist any force acting parallel to the grain about ten times as efficiently as they do one acting at right angles to it. As the storage tissue increases in amount this difference in the effective stresses on the two faces of the wood becomes gradually less until those woods with the highest ray volume show a compression strength parallel to the length of the fibers only five times as great as when the force is acting on the side of the block. The reason for the greater resistance when the forces are applied parallel to the length of the fibers is obvious when each and every one are considered as hollow columns in which

the greatest strains are developed when the stresses act through their longest dimensions, if, however, the rays be considered as hollow columns running at right angles to the fibers, any force which acts parallel to the vertical elements becomes one acting at right angles to the long axis of the individual ray cells in which case it becomes a compression perpendicular to and not parallel to their length. In other words, a block of wood under end compression develops two types of strain. In the fibers and other vertical elements it follows the laws of pressure on columns through their greatest dimensions, but the rays with their extreme length perpendicular to the lines of force develop a resistance comparable to the laws of physics governing the reaction of hollow tubes under side pressure. Since vertical strains in woody tissues are somewhere between 5 to 10 times as great as lateral strains, the final reactions of a block under endwise compression will represent the sum of the resistance acting parallel in the vertical elements and at right angles in the rays. Consequently, any increase in the ray volume per cent, other things being equal, would decrease the ultimate strength in proportion to the numerical increase in the storage tissue. Thus it would appear that the failure of woods under endwise compression to keep pace with the normal increase in density is the result of a cumulative reaction perpendicular to the long axis of the ray cells whose augmentation in volume is proportional to the increased weight of the specimen.

When pressure is applied to the radial face of the wood the strains in the vertical cells and the rays are both perpendicular to the grain, and as there are no counteracting forces the increase in resistance is roughly proportional to density and the correlated gain in the amount of storage tissue. On the tangential face, especially in soft woods even though the ray cells would naturally exert the greater strains in opposition to a force acting along their longest axis, this is more or less nullified, however, by a general tendency of the vertical cells to offer an even lowered resistance owing to their general brick-shaped form.

It would appear that the various degrees of resistance to compression in wood is to a large extent gauged by the internal organization and density, and that it is especially associated with differences in the ray volume owing to counteracting strains due to the location and direction of the different elements. In the same way, it might be that the resistance to shear is intimately correlated with that of ray volume.

The study of rays in the commercial timbers indigenous to this country must do more than merely tabulate their quantative per cent since a full knowledge of their significance can come only at least through an attempted interpretation of their relation to factors which have caused a change both in size and efficiency. This intimate knowledge of wood structure becomes even more important when compared with the more homogeneous man-made products like steel and cement whose reaction under specialized conditions can be predicted with only a small degree of uncertainty. Wood, on the other hand, is the product of a living organism and possesses all the variations incident to inheritance and environment, variations in anatomical structure which are the result of modifications due to inheritance, to transmitted alterations in the germ plasm, and to deviations engendered by the vicissitudes of growth. Inheritance perhaps plays the largest rôle since to it may be ascribed the main types of divergence between species, genera and families, but it, too, in the larger sense, may be the result of changing surroundings over an age-long period. For example, the conifers developed far back in the Mesozoic and passed through their greatest fluctuations when the climatic conditions were more uniform than at present, at a time when there was no need to prepare for a resting season by assuming the deciduous habit or by storing food for accelerated growth subsequent to periodic interruption. Consequently, the soft woods, becoming thus static in their evolution, possessed only a small amount of storage tissue, and when adverse conditions arrived in the late Cretaceous and later cold epoch, those species which could not endure the profound changes cease to exist and those which could, persisted, but with little change in their organization. Thus, though the small rays in conifers may be ascribed to inheritance, they must also be considered as the result of a stabilized evolution characteristic of a warmer and less hostile age. Those very periods of progressive refrigeration, aridity, or shifting climatic zones which caused the destruction of the more conservative and less adaptable conifers, and restricted other like *Sequois* to a limited area, brought into being a new, vigorous, and versatile race, the Angiosperms. This more recent addition to the plant kingdom had not become static when the changes came, and consequently, became more easily adjusted to an oscillating temperature. Thus, in response to seasonal changes the more sensitive internal mechanism of the Angiosperms caused a loss of leaves and in consequence the development of a larger storage system in the wood,

as well as a more elaborate circulatory apparatus in compensation for the elimination of foliar storage organs. The same abbreviated growing season which caused the deciduous habit, augmented the leaf-area in order that food manufacture might be accelerated during the more favorable months. The result of this more youthful resilience in the hardwoods took the form of an elaboration of the rays into variously shaped broad bands of storage tissue, while the uniseriate type so characteristic of conifers was relegated to a subordinate position. Although the conifers may be as efficient in the manufacture of the products for assimilation as hardwoods, their dissipated storage system must be more cumbersome in growth economy than the larger rays whose effective portion is more localized near the cambium where needed. It may thus be possible that this change in environment with its concomitant alterations in the anatomical structure may in large part be the cause for, and not the result of, rapid modifications which manifest themselves as new and numerous species.

In addition to these larger variations appearing in response to germinal diversity and to long periods of climatic change, there are other changes in volume due to more localized ecological conditions which, however, have been sufficiently discussed in the preceding paragraphs. As in the case of the larger alterations in ray tissue, the Angiosperms, owing to their youth and versatility, seem to be more responsive than the more ancient and less adjustable gymosperms.

Although the facts brought out in the tabulation of ray volumes in different species lend themselves readily to purely scientific deductions they also lend themselves just as readily to the more practical problems of utilization. Space does not permit, however, of a further discussion of this phase of the problem.

In conclusion I wish to thank Dr. H. P. Brown and Dr. C. C. Forsaith for their many suggestions and helpful criticisms in preparing this paper. For the wood samples used in this research work I am indebted to Dr. Brown for access to his collection at the college and also to Mr. Upson of the Forest Products Laboratories at Madison, Wisconsin.

SUMMARY

1. The larger variations in the volume of the rays in woods are due to inheritance resulting from long periods of change brought about by diverse ecological conditions. The smaller individual variations are the result of differences in site, climate, temperature, soil, age, the

location in the tree, the efficiency of the leaves, and the development of the deciduous habit.

2. The conifers show an average ray volume of 7.08 per cent and the hardwoods an average of 17.04 per cent. Diffuse porous woods and ring porous woods with diffuse rays show an average reduction of 2 per cent in the former. Deciduous species show a relatively higher per cent than does the evergreen type. Southern species, because of their longer growing period, show a higher ray volume than closely related species growing in the North. Trees with uniseriate rays, diffused rays, and compound rays show an increase in ray volume in the order given.

3. The presence or absence of vertical parenchyma does not affect ray volume. Relationship to any genus or family affects ray volume only in the most general way.

4. In the conifers, *Thuja occidentalis* presented a minimum ray volume of 3.4 per cent, *Pinus heterophylla* a maximum of 11.70 per cent and a general average of 7.08 per cent. In the Dicotyledons *Tilia heterophylla* was lowest with 5.30 per cent, *Quercus densiflora* was highest with 42.26 per cent. The general average was 17.04 per cent.

5. Variations in ray volume are closely associated with numerical changes in specific gravity, hardness, modulus of rupture and compression perpendicular to the grain. Compression parallel to the grain shows a lower increase in relation to a gain in ray volume owing to the direction of the rays. Shearing strength is influenced by ray volume.

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STUDIES OF THE DISTRIBUTION AND VOLUME OF THE WOOD RAYS IN SLIPPERY ELM (*ULMUS FULVA* MICHX.)[1]

By W. J. DeSmidt

Conspicuous among the anatomical features of wood are the wood or medullary rays which appear as bands or strips of tissue extending for varying distances from the bark toward the pith. In contrast to the vertical elements which have their long axes arranged longitudinally in the tree, the wood rays consist of cells which are prolonged horizontally and differ from the vertical elements not only in pitting and function, but likewise in their smaller size and the nature of their walls. As the wood undergoes utilization they react differently than do the vertical elements and their relative abundance or paucity undoubtedly does affect materially the properties of wood.

Owing to the conflicting results presented by European writers in this field and the dearth of data on American trees, it has seemed advisable to study in detail the ray content of an indigenous species. Since the wood rays of conifers are minute and their utilization in a study of this sort would lead to obvious difficulties in technique, a hardwood with multiseriate rays of the diffuse type was accordingly chosen for the investigation. Slippery elm was selected from the trees available on the Forest Experiment Station at Syracuse, N. Y. The subsequent study has shown that uniseriate as well as multiseriate rays abound in this wood and raises the question whether any of our hardwoods are characterized wholly by the multiseriate type.

Tree I was a typical example of this elm as found in central New York and measured 74.25 feet in height with a stump diameter of 13.7 inches. The bole forked 33.75 feet above the ground to form the rounded crown, characteristic of the species.

Tree II and III were situated within a radium of 100 feet and were felled in part to obtain results which could be used as a check on the first tree, in part, because they afforded variations in age and eccen-

[1] A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science, in the Department of Wood Technology, New York State College of Forestry. 1920.

tricity which were not present in Tree I. Tree II was one of a clump of five sprouts which had resulted from coppice growth. The total height was 22 feet and the first branch was 9.5 feet above the ground. It leaned toward the south and received full light only from this direction. Tree III, measuring 21 feet in height, grew in the open: was one of a clump of three sprouts of about equal size.

Small blocks suitable for the preparation of microscopic mounts, including the last annual ring in the root, trunk, and crown, were taken from Tree I. In addition, material was collected from a root at various distances from the pith along two radii. The root proved to be very eccentric; the radius on the upper side was 3½ times as long as that of the lower side, measured from the pith. On the longer radius samples were taken 1 to 1⅖ inches apart from six points, including the last annual ring and a section ⅛ of an inch from the pith. Four cuttings were made on the shorter (lower) radius at intervals of about ⅖ of an inch.

In a similar manner, except at 10-year intervals beginning at the last annual ring, blocks were obtained at stump height along the long, short and north and south radii. Again at a height of 18.3 feet a like series of cuttings were taken except that in this case the north and south radii were identical with the long and short radii, respectively, necessitating but two series of cuttings.

In Trees II and III where the growth had been rapid, material was collected at stump height at various distances from the pith along the north and south diameter.

The method employed in making the calculations of ray volume consisted in the use of a B. and L. G. S. M. photomicrographic apparatus. In place of an 8/10 plate, P. M. C., bromide paper was exposed at 100x magnification and developed, the result being a negative rather than a positive on the paper. Inasmuch as the contour and area of wood rays were alone desired, this in no way interfered with the work in hand. This method proved the more satisfactory in that the results were quickly and easily obtained and possible error in tracing rays eliminated.

Summation of data was varied somewhat according as the rays were uni or multiseriate. In the latter case the area of the entire field and of each multiseriate ray and ray part was measured by means of a planimeter graduated to 1/100 square inch.

Both uniseriate and multiseriate rays abound in the wood. The former, as the term applies, are a single cell in width and vary in height from 2 to 8 cells. They are scattered among the larger rays and so far as could be determined, undergo neglible changes at the different ages except an increase in height through the addition of extra cells. The multiseriate rays vary in width from 2 to 7 cells and, as seen in tangential view, assume the form of a biconvex lens. The height is variable, ranging from four to a hundred or more cells. As is commonly the

TABLE 1.—*Ray Variations at Different Heights. Last Annual Ring.*

Number of sections	Number sections examined	Height in tree (meters)	Distance from pith (mm.)	Number of rays per sq. mm.	Volume per cent each kind	Total volume, per cent	Dimensions and areas of average rays		
							Height (mm.)	Width (mm.)	Area (sq. mm.)
—1	2	Root —1.0	94.5	[2]17.4 [3]18.6	14.34 1.81	16.15	24.11 10.70	3.42 0.91	82.42 9.73
1	4	0.61	164.0	14.8 20.8	13.86 1.91	15.64	30.23 11.20	3.09 0.82	93.65 9.18
2	2	3.05	134.0	13.5 23.0	9.23 2.40	11.62	25.65 12.07	2.66 0.86	68.37 10.43
3	2	5.49	114.8	15.7 16.0	9.84 1.79	11.62	25.45 12.18	2.46 0.92	62.67 11.19
4	2	7.93	100.0	14.8 25.7	8.69 2.10	10.79	27.55 10.42	2.13 0.78	58.72 8.17
5	2	10.36	75.0	14.8 24.3	9.77 2.29	12.06	27.77 11.16	2.38 0.84	66.01 9.42
6	4	12.80	47.4	18.0 27.3	8.20 2.23	10.43	24.26 10.37	1.87 0.79	45.55 8.17
7	5	15.24	26.9	21.6 22.7	10.67 2.42	13.09	22.35 11.25	2.29 0.95	49.39 10.66
9	1	17.68	9.0	29.8 31.8	10.63 2.75	13.38	14.59 9.60	2.45 0.90	35.67 8.64
10	1	20.11	4.0	24.3 22.9	5.97 2.02	7.99	17.87 9.80	1.37 0.90	24.57 8.82

[1] The area of rays per unit area is to the unit area as the volume of the rays per unit volume is to the unit volume.
[2] Multiseriate rays. [3] Uniseriate rays.

case in other woods, there is an extended system of air spaces between the cells which communicate with the lumens by simple pits. In shape and pitting, the cells of the multiseriate ray conform to those of the uniseriate type. Ray idioblasts, comparable to the vertical series, may be found in either form of ray and were especially abundant in root-wood.

The observations on Tree 1 may now be discussed to advantage Sections were prepared from material collected from Tree I at heights as indicated in Table 1. These included one root cutting at a distance of 1 meter from the root-crown and hole cuttings at intervals of 2.49 meters (8 feet) beginning at 0.6 meters (2 feet) above the ground. Table 1 represents a summation of the results based on averages.

As indicated in the table two numerical optima for multiseriate rays occurred in Cuttings 9 and 1 respectively, that is, well up in the crown and in the root. Cutting 9 exhibited the maximum with 29.8 rays per square millimeter while the ray count of the root was 17.4. The number of rays in the bole including the base of the large limb above the first fork Cutting 5, showed but slight fluctuation, varying between 13.5 and 15.7 while there was a slight decrease of the ray count in the ultimate twigs as shown by Cutting 10.

The maximum count of uniseriate rays occurred in Cutting 9 in the upper part of the crown, that is, at the point of optimum for multiseriate rays. From this point as in the case of the multiseriate type there was a decrease into the the ultimate twigs and into the branch-free bole which, however, apparently followed no definite law and was subject to fluctuations comparable to, but not concomitant with those of the multiseriate rays.

With the exception of Cutting 10, the uniseriate rays surpassed the multiseriate in numbers at every instance. The greatest discrepancy occurred in Cutting 4, the least in Cutting 3. In general (Cutting 3 excepted), the preponderance of uniseriate rays was the more accentuated toward the base of the crown and in the branch-free shaft, but not in the root.

The results enumerated above, most notably a maximum ray count in the higher part of the crown, are at variance with those of some of the earlier investigators as shown by Essner (*3*), who states that there is a decrease in ray number per unit of surface at higher elevations in the stem in *Pinus strobus L.* Hartig (*4*) also found a decrease in ray volume in *Quercus rubra* as the crown was approached and as-

cribed this to a diminution in the number of large rays. Jaccard (5), on the other hand, deduced from his observation upon *Picea excelsa* and *Abies pectinata* that the maximum number of rays occurred some 10-15 centimeters above the ground. Higher in the stem a minimum was reached which was again followed by an increase at the base of the crown. In his subsequent paper incorporating his observations on *Sequoia sempervirens* and *Picea omorica*, he states that the ray number was at a minimum in the lower third of the stem whence it increased quite regularly into the crown and toward the root-crown. He fails, however, to mention the point of maximum.

The data in Table 1 substantiate in part that of Jaccard. In *Ulmus fulva,* the maximum ray count was found to be well up in the crown. Toward the base of the crown and in the bole, both uniseriate and multiseriate rays are fewer in number, the minimum in each case coming in the lower part of the stem. The multiseriate type subsequently increased in number again as the roots are approached. Whether the same is true of the uniseriate rays. as the tree increases in age, is problematical. A decrease occurred in Tree I, but unfortunately no data is available for the root crown.

The total volume (Table 1, column 7) was at a maximum in the root (16.15 per cent) and stem-base (15.64), a condition which was to be expected in that the larger roots are primarily storage organs and contain large amounts of reserve food during the winter months. In the shaft and base of the crown less storage occurs owing, no doubt, to the fact that the tree is concerned in developing a larger crown and greater root system, and growth sufficient to retain the necessary symmetry only, is going on in these regions. A second optimum occurred in Cutting 9, the point of maximum ray number, occasioned no doubt by a demand for reserve food which could be used in the spring not only in forwarding secondary growth but growth in length as well. This data substantiate the observations of Bertog (2) in which the root, the lower part of the bole and the crown exhibited the highest ray volume.

The volume of the multiseriate rays surpassed that of the uniseriate at every instance even though the uniseriate type were numerically more numerous. The extremes in this respect are found in Cuttings 1 and 10 where it amounted to 7.9 and 2.9 times that of the uniseriate form respectively. A striking discrepancy likewise occurs if the volume per cent of the uni and multiseriate rays are considered separately in

comparison with the total ray volume. That of the multiseriate rays exhibits two optima which correspond to the total volume optima, namely, a maximum at the base of the bole and in the root followed by a second increase in the upper part of the crown. The maximum volume per cent of uniseriate rays on the other hand is in the crown, corresponding to the upper optimum for multiseriate rays and occurring in regions where uniseriate rays are somewhat augmented in number. It decreases at lower altitudes in the stem without subsequently increasing perceptibly as the shaft-base and roots are approached. The volume of uniseriate rays per unit volume, in contrast to the total ray volume, is at a maximum in the crown of the tree.

Of interest in this connection is the cross sectional area of average rays (Table 1, column 10). The uniseriate rays exhibit but slight variation in area at different heights in the tree while the multiseriate rays are from two to three or more times as large in the root and stem-base as in Cutting 10. That multiseriate rays exhibit a reduced cross sectional area at higher elevations in the stem, is to be explained in that their width is proportionably greater than their height toward the stem-base and in the root and restricted at higher elevations in the bole and crown.

Data were next collected in an endeavor to determine ray fluctuations at varying distances from the pith and the results of observations at stump height, Section 1 (height 0.6 meters), Section 3 (height 5.49 meters), and Section 1 (root) are incorporated in the following paragraphs.

The wood rays at stump height were investigated on the long, short, and north and south radii at intervals of 10 years, beginning at the last annual ring. Table 2 gives the results of the data obtained in this way for the long radius only.

The broad rays were most numerous[2] in the inner (first formed) rings of Tree I and decreased outward, a condition which was to be anticipated in that at higher elevations in a given annual ring, like increases occurred.[3] On the long and north and south radii the number was reduced by approximately half, on the short radius by about one-fifth. At the same time the area, width, and height varied in in-

[2] The maximum number occurred in the first annual ring on the north and south radii. A minimum corresponding to the ultimate-twig minimum was evident in the first ring on the long and short radii.

[3] Data taken along a radius at a given height should substantiate at least in part that obtained from the same annual ring at different heights.

TABLE 2.—*Ray Variations at Stump Height at Ten-Year Intervals.*

Age	Distance from pith (mm.)	Width annual ring (mm.)	Number of rays	Volume, per cent each kind	Total volume, per cent rays	Dimensions and areas of average rays		
						Height (mm.)	Width (mm.)	Area (sq. mm.)
8	12.5	1.0	[1]26.0 [2]32.0	9.65 3.51	13.16	19.85 11.92	1.87 0.92	37.11 10.96
18	24.0	2.5	30.5 29.4	11.93 2.47	14.40	20.13 10.18	1.94 0.83	29.11 8.40
28	52.0	3.5	25.1 22.5	13.63 1.88	15.51	24.72 9.81	2.20 0.85	54.32 8.35
38	88.0	3.0	18.2 27.3	13.76 1.58	15.34	30.15 9.33	2.51 0.62	75.56 5.79
48	122.5	2.5	18.9 29.1	13.30 1.87	15.17	21.94 8.31	3.21 0.77	70.37 6.43
58	150.0	2.0	14.4 27.3	10.89 1.78	12.67	26.96 9.96	2.81 0.65	75.83 6.52
68	190.0	4.0	13.6 27.0	13.47 1.81	15.28	30.15 11.76	3.27 0.57	98.82 6.70

[1] Multiseriate rays. [2] Uniseriate rays.

verse proportion, increasing strikingly in every case and paralleling the condition found in a given ring at various heights. Areal dimensions of an average multiseriate ray increased approximately one and one-half to three and a half times in a period of sixty years. The narrow rays were found to exhibit less though more irregular fluctuations than the multiseriate; in other words, they were more conservative. There was a tendency toward a restriction in ray numbers in the outer rings. With the exception of the north radius, the area of the average ray was largest near the pith; then appeared a decrease, followed again by an increase which, however, was not concomitant on the four radii. At the same time corollary, though not identical, fluctuations appear in width and height.

As was to be anticipated, two optima for total ray volume were evident. The first and lower, which corresponded to that of the crown-volume, Table 1, occurred between the 8th and 28th rings. Maximum total ray volume was found in the outer layers and was obviously

identical with that of Table 2. The volume per cent of uniseriate rays proved to be greatest near the pith, while the inverse held to be true in the case of the multiseriate rays. The larger volume of the latter led to the maximum total ray volume of the outer rings. It must not be inferred from the foregoing, however, that there was an exceptional gain in ray volume during the 80-year period. The greatest increase occurred on the north radius, but in this case was restricted to 4.6 per cent. The average gain on the four radii proved to be but 2.3 per cent. It may therefore be concluded that the ray volume increases slightly with increasing age, while the multiseriate rays diminish in number but increase in size.

Numerical fluctuations occur in the rays of both types on the two radii of the root which apparently are irrespective of the distance from the pith. The same may be said of the ray dimensions. In the 20th ring on the longer radius the area of the average multiseriate ray was 97.87; it then decreased and subsequently increased between rings 33 and 45. The maximum (101.11) was reached in the last ring (68) where the greatest increment growth was attained on this radius, indicating a close correlation of ring width with ray area. On the shorter radius the area of the average multiseriate ray actually decreased during the last ten years (from 80.35 to 67.74) because here the growth was more restricted, necessitating smaller rays. At the same time a comparable reduction took place in the uniseriate rays.

Trees II and III offered exceptional advantages for comparison with Tree I since they had arisen through coppice growth and exhibited wide annual rings. Including the first and last seasonal zones, a series of four cuttings were taken at regular intervals at stump height on the north-south diameter.

In both trees the ray fluctuations followed in general those of Tree I. The broad and narrow types were most numerous and their areas most restricted in the innermost rings. As the periphery was approached ray dimensions increased. At the same time the total ray volume increased owing to the augmented size of individual multiseriate rays.

It is of interest in this connection to note the result of coppicing on ray content. Coppice sprouts have an immense root system upon which to draw and consequently exhibit very rapid growth with which is correlated a higher ray volume. Such an increase may seem heterodoxical owing to the presence of the old root system, but may be explained through the formation of large quantities of reserve food

accruing from greater leaf surface per unit volume, which nature stores in the more readily accessible regions of the stem.

In conclusion, the data obtained from Trees II and III may be said to bear out that of Tree I. The maximum total ray volume occurred in the tenth (outer) ring and corresponds to the upper-crown optimum of Tree I. An apparent anomaly arose in that there was a decrease in ray numbers beginning with the first annual ring (note the increase in Tree I, Table 1), which is to be ascribed to wider zones resulting from coppice growth. The total ray content of such wood is in general higher than that of normal wood and is traceable to an increase in the volume of the multiseriate rays accompanied by a reduction in number.

The maximum ray width occurred in the springwood part of the ring in every case, that is, at a time when the rays were still high but not at their maximum height (highest in outer summer wood). Following this there was a decrease in ray width to a minimum which occurred somewhere in the first formed summer wood. As the boundary of the ring was approached the width again increased to the maximum, which was attained in the first formed spring wood of the following year. It follows that the multiseriate rays should attain the greatest cross sectional area and hence volume in the spring wood portion of the ring where ray width and ray height are both appreciably high.

The multiseriate rays of the stem wood, like the vertical elements (*1*) increase in size centrifugally from the pith, a fact which is substantiated by the studies of the last annual ring at different heights and of successive rings in cross sections of Tree I. This enlargement may be traceable in part to increased dimensions of ray cells which are contemporaneous with like changes in vertical elements in the earlier rings (approximately 30) and owe their origin to larger cambial intials in the lateral meristem. But in the aggregate it is due more to greater ray dimensions, particularly width, occasioned by an increase in cell numbers and continues in slippery elm for years after cell size has attained a maximum. In Tree I, the oldest of the three trees, the multiseriate rays were still undergoing enlargement in the 68th ring.

The uniseriate rays, to the contrary, remain of approximate size throughout successive rings or at best are but slightly larger in regions proximate to the pith where the difference is so slight as to be neglible. Throughout they are found to fluctuate less than multiseriate rays, not only in size, but in numbers as well, a fact which may be ascribed to their small size and natural conservatism.

A careful count of the numbers of rays and their area shows that *in the upper crown the ray volume optimum is due to an increased number of multiseriate rays of restricted dimension. At the stem-base the second optimum is due to an increase in the volume of the average large ray which offsets a reduction in number. In the root the third optimum is due both to size and number. The uniseriate rays, to the contrary, remain nearly constant in number or increase slightly at points of ray optimum.*

Local fluctuations in the size of multiseriate rays which are independent of the general ray variations noted above occur normally within the boundaries of annual rings in slippery elm. Ray enlargement at the boundaries of the growth zones is a characteristic feature of many dicotyledenous woods and is evidently correlated with a need for more storage tissue toward the close of the season since secondary growth begins in the spring in such trees before the leaves have attained a size sufficient to become an appreciable factor in the manufacture of food. Nature accomplishes this through a heightened osmatic pressure in the cells concerned which is, however, most effective in the spring because neighboring cells are most plastic at that time. The thick-walled summer wood elements in the outer part of the ring preclude maximum enlargement of ray cells toward the close of the growing season, but the tendency is expressed in an increased ray volume which attains its greatest development in the spring wood of the following year.

SUMMARY

1. The multiseriate wood rays of *Ulmus fulva* Michx. fluctuate appreciably in size and number not only in different trees but in the same individual. These variations are in part general and develop over a period of years, in part local, and arise within the boundaries of a ring during one growing season. The uniseriate rays vary in numbers but not appreciably in volume in various tree parts.

2. Multiseriate rays are most abundant near the top of the crown. They decrease in number in the ultimate twigs and at lesser heights in the stem. A second numerical optimum occurs in the root and possibly in the root-crown.

3. The uniseriate rays are most numerous in the upper part of the crown. At lower elevations in the stem and in the root they exhibit minor numerical fluctuations but are more conservative throughout than the multiseriate rays.

4. The multiseriate rays increase in width and volume toward the stem-base and in the root. The volume of the uniseriate rays is slightly larger in the first rings of the stem, but fluctuates little throughout the tree.

5. Total ray volume is at a maximum in the root and stem-base. It remains fairly constant in the bole, but increases again to a second optimum in the upper portion of the crown. The crown optimum is due to an increase in the number, the stump optimum to an increase in the size of the multiseriate rays. In the root maximum ray volume is attained by an increase in the number and size of multiseriate rays.

6. Cross sections of the stem repeat in general the ray fluctuations which are to be noted at different heights.

7. Local fluctuations in the size of multiseriate rays arise within the boundaries of annual rings. They attain their greatest volume in the spring wood portion where ray width and height are appreciably high. The minimum volume is found in the first formed summer wood.

8. Local fluctuations of secondary nature are correlated with varying ring width. In wide rings an increase in the size of multiseriate rays occurs which is generally accompanied by a reduction in ray number; in narrow rings the reverse applies.

In conclusion, the writer wishes to express his sincere thanks to Dr. H. P. Brown and Dr. C. C. Forsaith for their helpful suggestions during the preparation of this paper.

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ALASKA'S INTERIOR FORESTS

By John D. Guthrie

U. S. Forest Service, Portland, Oreg.

Broadly speaking, when one writes about Alaska's interior and its forests one is dealing largely with an undiscovered country, as far as exact figures are concerned. Here is an area comprising not less than 300,000 square miles, or 192,000,000 acres, of which less than 300,000 acres have been sectionized. From the time of the Russians many individuals have passed over portions of this immense area, and a few have remained there, but they have been interested mostly in the geology of the country, what was in the ground and not what grew on the surface. Therefore, figures dealing with the acreage of forest land, the geographic range of tree growth, the total stand of timber, the loss by forest fires, or the area burned over—things in which a forester would be most interested—must be the merest approximations. Men have gone into the heart of Alaska primarily for fur and for gold, not for timber.

If you read through the dozens and dozens of U. S. Geological Survey reports and bulletins, or the International Boundary Commission reports, or the few other publications available, you will find here and there a mention, a paragraph or so, dealing with the forests of the interior of Alaska. Mention will be made of the character of the forest, its species, the evidence of forest fires, and there is even a map showing the approximate forest area of interior Alaska, but that is about all. The notes on record dealing with the forests of the interior country have been merely incidental. Data regarding Alaska's coast forests is fairly abundant and approaches the accurate. Several foresters have made very hurried trips through the interior, all following the beaten paths of travel, and there is one forestry publication.

There are, however, certain broad statements that may be made concerning the interior forests of Alaska which cannot be disputed. These are that there is a very extensive area bearing forest, much of which is of saw-timber size; that the tree species have been pretty accurately identified; that the forest area has been very extensively burned-over; that the forest has played a very important part in the

development of the country that has come about; and lastly, that apparently it has not been of very much interest to anyone whether forest fires continued or not."

The following notes are based on a month's trip through the interior in 1920, supplemented by later references to many government publications.

GENERAL EXTENT

The forests of interior Alaska are estimated to comprise not less than 150,000,000 acres. They are entirely on the unreserved, public domain of the United States and so far have been given little or no administration nor any protection from fire. Although the market value of this large area of government timber is comparatively little, the value of these forests in the future development of the immense region is hardly possible to measure. In the consideration of a forest policy for the nation this immense Government-owned forest area should not be overlooked; it would seem to be good business at least to protect these lands from uncontrolled forest fires, against the time when they will be vitally needed not for use in the States but in the development of both mineral and agricultural lands of the interior, which development is sure to come. Alaska not having as yet even the full status of a territory, the title of approximately 99 per cent of its immense area still remains in federal ownership. Of its coast forests approximately 90 per cent is included in National Forests and has been under administration since 1902, and since January 1, 1920, administered as a separate forest district with headquarters at Juneau. The 20,000,000 acres of National Forest lands have played a most important part in the development of those portions of the Territory in which they are located, with indications pointing to their playing an even greater rôle in bringing to the Territory permanent industries. The coast forests will undoubtedly become within a comparatively short time an important factor in exports of pulp and paper to the United States. It is not believed, however, that the interior forests will furnish products that will ever prove feasible or practicable for export outside of the Territory of Alaska, nor would such a movement be advisable, for it is believed that every acre of the interior timber will be needed for internal development which must come to the interior basins of Alaska's great river systems.

The forests of interior Alaska are practically confined to the great basins of the Yukon and Kuskokwim Rivers. Some idea of the size

of these areas may be judged when it is stated that the drainage basin of the Yukon, the fifth river in size in North America, embraces 330,000 square miles of which slightly less than one-half is within the Territory, while that of the Kuskokwim covers 50,000 square miles. It is probably not generally known that the United States owns forests within the Arctic Circle, yet the range of tree growth in central Alaska extends up the Chandlar and tributaries of the Porcupine Rivers, inside latitude 68°50′, or 2° inside the Arctic Circle.

The interior forests are totally unlike Alaska's coast forests, as to size, density, and species. They are for the most part of the woodland type, but are fairly comparable to the forests of northern Maine and Eastern Canada, both as to species and mixture, though inferior as to quality. Of the estimated 150,000,000 acres of interior forests, there are probably 75,000,000 acres which bear timber of sufficient size and quality to make it of extreme value for cordwood, sawlogs, boat building, mining operations, farm use, and other needs of a pioneer region.

SPECIES.

The principal tree species represented in the interior forests are white spruce (*Picea canadensis*), white birch (*Betula alaskana*), balsam poplar (*Populus balsamifera*), black cottonwood (*Populus trichocarpa*), aspen (*Populus tremuloides*), black spruce (*Picea mariana*), and tamarack or larch (*Larix alaskensis*). Of the above species white spruce is by far the most important tree. White birch is widely scattered and comprises a large percentage of practically all stands. Black spruce, while fairly abundant, is confined largely to muskegs and swampy areas and is of little value. Poplar and cottonwood are abundant along streams while aspen with white birch usually forms the tree cover at timber line, which is as a rule about 2,500 feet above sea level. Tamarack is scattered in river and creek bottoms but is unimportant. The best stands of timber are found in the valleys, particularly along the Susitna, Tanana and Porcupine Rivers.

GROWTH AND STAND

The stand of the interior forests varies greatly with the elevation above sea level and the exposure. Broadly speaking, the valley floors of the Yukon and its main tributaries, as well as the Kuskokwim, the Copper, the Chulitna, and the Susitna Rivers, are timbered

with fairly heavy stands of white spruce, white birch and cottonwood. As one leaves the valley floor and begins to ascend the slopes, the forest becomes scattered and the trees become shorter and more limby, until an average elevation of some 2,000 feet above sea level is reached when tree growth ceases. There is forest practically along the entire line of the Government railroad from Anchorage to Fairbanks (353 miles), except immediately in Broad Pass and except where the timber has been entirely destroyed by extensive fires.

Former Governor Thomas P. Riggs, of Alaska, who has spent many years in the Territory both as a member of the U. S. Geological Survey and the International Boundary Commission, estimated that there were 8,600 square miles or 5,504,000 acres of merchantable saw-timber in Interior Alaska, and that this would average not less than 5,000 board feet per acre. On this estimate there would therefore be a total of 27,520,000,000 feet, board measure of merchantable saw-timber; the above estimates do not include timber suitable only for fuel and mining purposes, such as stulls and lagging.

Prindle[1] places timber line in the Yukon basin at about 2,500 feet above sea level. He states "there is a minimum of vegetation on the high ridges and their rock-strewn slopes, and a maximum in some of the larger valleys of tributaries to Tanana River. The upper zone of vegetation is characterized by more or less grass, lichens, moss, low bushes, and particularly by dwarf birch and alder. On many ridges of intermediate height the growth of dwarf birch is very dense. Most of the lower ridges and spurs near the main drainage lines are covered with a dense growth of small spruce. In the large valleys timber is more or less abundant, especially on the sunward-facing slopes of the valleys near the main drainage lines and over portions of the valley floors. Considerable timber is more than a foot in diameter; spruce predominates, but poplar and birch are abundant in places, especially in the vicinity of Tanana, where tamarack is also common." He calls attention to the striking feature of the distribution of tree growth in the contrast between the upper valleys of tributaries of the Yukon and those of the Tanana. Most of those of the Yukon are comparatively bare or at most are dotted only with scattered groups of spruce, while those of the Tanana are thickly timbered from their heads.

[1] A Geologic Reconnaissance of the Circle Quadrange. L. M. Prindle, U. S. Geol. Survey, Bul. 538, pp. 19-20, 1913.

As is to be expected from a region in this latitude, with long, cold winters and short, hot summers with almost 24 hours of sunlight, and with a rainfall averaging less than 15 inches, all tree growth is slow. However, a maximum temperature of 95° Fahrenheit has been recorded in the Yukon basin, and on specially favored sites annual plant life becomes almost tropical under rays of an arctic sun. Actual measurements of the growth of trees, however, show a far more rapid rate of growth than would be expected, a growth that compares very favorably with like tree species in the northern portions of Maine and eastern Canada.

From measurements taken by Kellogg [2] in 1909 in the Fairbanks region and by Drake [3] in the lower Susitna drainage, white spruce makes an average diameter growth at the butt of one inch in 8.7 years, and an average height growth of 10 inches yearly. The writer measured young white spruce in favorable sites near Fairbanks which averaged 6 feet in height, with ages of 9, 10, and 11 years, and many young trees with a height growth of 12 inches in one year. The most rapid diameter growth measured in the Fairbankss region was 2½ inches for a 10-year period. Measurements for white birch in the lower Susitna region gave a maximum of 2.60 inches in diameter in 10 years. Considering the short growing season at this latitude this is a very satisfactory rate of timber growth. On the edges of partially burned areas, where soil and light conditions are especially favorable, so rapid and thrifty has been the height growth of young white spruce that this new growth has been seriously considered by some to be a new species that has come in, as is often claimed by uninformed persons in cases of thrifty young growth.

In stands of white birch and white spruce along the lower Susitna, Drake reports that maximum stands show as high as 30 cords of birch per acre and that wood cutters have cut as high as 41 cords per acre of all species on areas near Anchorage, also that tie cutters have cut 84 spruce ties per acre from these stands. Single acres on Peters Creek, in the lower Susitna drainage, have yielded 400 linear feet of spruce piling. He also reports that a Mr. L. W. Turner in 1916 operated a sawmill on a tract on Eklutna River that cruised 10,000 board feet per acre of cottonwood on 100 acres. A large area along

[2] The Forests of Alaska. R. S. Kellogg, F. S. Bul. 81, U. S. Dept. of Agric., 1910.

[3] Mss. Report, "The Birch-Spruce Forests of the Upper Cook Inlet Region." G. L. Drake, 1921.

the Matunuska River near Eska Creek is reported to run from 15,000 to 20,000 board feet per acre.

PRESENT USE OF TIMBER

As is to be expected in a region of long and cold winters, the bulk of the timber cut in interior Alaska is for firewood, probably several times as much timber being used each year for fuel as is used for lumber; as to even an approximation of the amount so used there is absolutely no authentic data. Wood has furnished the country with heat, light and power, though now native coal is beginning to be used since the completion of the Government railroad which traverses a country rich in coal deposits; in 1920 lignite was being mined at Healy, shipped over the Government railroad to Fairbanks, and sold for $9 per ton. In addition to furnishing a part of the supply of firewood the spruce has been sawed into lumber at the several small sawmills in the interior. Ten years ago there were sawmills operating at Rampart, Council, and along the Copper and Susitna Rivers, and also at Eagle and Fort Gibbon, and three mills were operating at Fairbanks. Because of the temporary depression on account of the high cost of operating and the low buying power of gold, placer mining in the interior is at a low ebb and consequently few of these sawmills are operating at present. With the recent completion of the Government railroad, however, prospectors are coming back to the interior, and with labor and supply costs somewhat lower a mining revival is looked for. The chief uses of lumber from the interior mills are for flume and sluice boxes, boat building, and houses and business buildings in the towns. The portion of the Government railroad from Anchorage to Fairbanks, a distance of some 353 miles, has been laid on ties cut from the forests along the right of way. The local timber has also been used almost entirely for camps and general construction work on the railroad, although most of the heavy timber for temporary bridges was shipped in from Puget Sound.

FUTURE USE AND EXPLOITATION

Even with the most careful handling the forests of interior Alaska will probably not fully supply the future needs of the country if it is to reach that stage of development which its untouched resources would indicate must come. Alaska is a country of vast distances and a scanty population, and as yet with meagre facilities of transportation, and wood always an essential product everywhere in a new

country, will be needed in enormous quantities. The availability of a timber supply close at hand will make sure the establishment and building up of the chief industries of the interior country, mining and agriculture. Interior Alaska has a climate not dissimilar to that of the Dakotas and with its agricultural posibilities, already proved at Fairbanks and in the Matanuska Valley, there will come a population commensurate with its resources. In the Tanana Valley alone there are estimated to be 1,000 square miles of land suitable for agriculture.

From observations made in 1920 in the Fairbanks region the farmers were at that time better off than any other class. Good crops of oats and potatoes and other hardy vegetables were being grown as well as fine crops of wheat which, ground at a local co-operative mill, suplied much of the interior population with flour. Eventually interior Alaska will produce by far the larger part of the more comonly used food products (such as flour, reindeer meat, and the hardier vegetables), for the needs of her interior population as well as posibly a surplus for much of the coast population to the eastward.

Already in the Fairbanks region, largely because of uncontrolled forest fires, the pinch for readily accessible timber is being felt, timber suitable for boat and building purposes having to be rafted on the rivers for distances from 25 to 60 miles. Cordwood of second-growth birch is more accessible. The economic importance of Alaska's interior forests will grow with the development of her mining and agricultural industries.

POSSIBILITY OF FOREST INDUSTRIES FOR EXPORTS

Even if it should never be needed for local development, because of its smaller size and relatively inferior quality, the timber of the interior forests can never compete as lumber with either the large timber of Alaska's coast forests or with that from the Pacific Coast States. More than once it has been seriously urged that the interior forests present great opportunities for an export trade in the manufacture of pulp, or for the location of wood-using industries, furniture plants, or other minor forest products. The species composing the interior forests are admirably suited for pulp, and are the same species that have been used by eastern pulp and paper makers for many years. However, the cost of transportation, the enormous area of forest land involved, and the absence of very large stands of timber in compact bodies, would make the plan of utilization of these

forests for pulp export entirely too chimerical. With the development and setlement of the interior the establishment of small pulp and paper plants, the product for local use in Alaska, may however, eventually prove practicable.

The Alaska birch while making good growth is much more defective than the eastern or paper birch. From Drake's studies made in the upper Cook Inlet region he found that practically all birch over 8 inches in diameter breast height is either stained or in an advanced state of decay, with the heart wood usually changed to a chalky pulp. This defect is not the ordinary "red heart" of the eastern paper birch which is not a disease but merely a color stage in the formation of the heart wood. From actual measurements taken by Drake in this region it was found that for trees over 8 inches in diameter, only 7 per cent were sound, while 43 per cent were stained and 50 per cent were rotten-hearted. This defect in Alaska birch is a serious drawback to its possible utilization since in the various wood-working industries that use birch only the white wood of the tree is utilized.

Alaska's interior forests are found along her stream valleys where they will be accessible to the mineral (quartz) development in her hills and mountains and handy for use in bringing under cultivation her imemnse areas of potential farming lands. A large amount of land along the valleys, now in forest, will undoubtedly be either destroyed by placer mining operations or be cleared for agriculture, since the best tree growth occurs on the best agricultural soil; this will reduce very materially the total forest area, thus necessitating the safeguarding and protection from needless burning of the remaining forest lands.

REFORESTATION AND FIRE PROTECTION

It is believed that the interior forests of Alaska are hardly holding their own against the annual loss in volume due to uncontrolled fires. Forest fires probably came in with the white man,[4] and it is estimated that roughly 25,000,000 acres of these forests have been burned over.

[4] In this connection Brooks says of the interior forests: "Large quantities are annually destroyed by fire, for which the natives must largely be held responsible. The writer has remarked again and again that the Alaska Indians are utterly careless about forest fires. It seems probable that they deliberately burn over large tracts in order to somewhat reduce the insect pest. That this indifference to forest fires was not learned of the white man is shown by the fact that many tracts are found which must have been burned over long before the appearance of any foreigner." From "Geography and Geology of Alaska," by A. H. Brooks and others, U. S. G. S., Prof. Paper No. 45, pp. 41-42, 1906.

Millions of acres have been burned over two or three times leaving an utter waste. Kellogg gives as his opinion that 10 times as much timber has been burned in the Fairbanks region as has been cut for fuel or lumber. Graves [5] estimated in 1915 that in the previous 20 years forest fires had burned over an average of one million acres per year in interior Alaska, and that in 1915 alone several million acres were burned. Travellers through the interior during the summer months are certain to see numerous forest fires burning and no attempt being made to control or extinguish them.

As typical of the situation, the writer saw a forest fire north of Copper Center on Sept. 3, 1920, that had covered several hundred acres and was said to have been burning since June; between Chittna and Fairbanks, a distance of some 320 miles, he saw on this same trip not less than eight forest fires burning along the Richardson Trail.

There is no agency, governmental, territorial or private, that realizes its responsibility for the protection of the interior forests from fire, and fires are not fought unless they threaten someone's private property. In a region with less than 15 inches of rainfall and under practically 20 hours of sunlight each day for four months each summer, the interior forests become very inflammable, and a spark in the dry moss may start a fire that may cover thousands of acres before burning itself out on the edge of a muskeg or being put out by the fall rains. In the past forest fires have usually followed the prospector and settler and the establishment of a mining camp has meant burned forests in that region; hunters also are to blame for some fires.

To meet the future demand for wood and in order to remedy the damage done by fire it has been seriously suggested that the Government should undertake extensive replanting of the burned areas. Artificial reforestation of denuded areas is an expensive undertaking in the States where labor costs are lower, transportation available, and climatic factors most favorable for tree growth. It costs an average of $10 per acre to grow and set out 2-year Douglas fir seedlings on denuded forest land in Oregon and Washington, where the climatic conditions are the best for the success of artificial restocking. In the interior of Alaska, with short, hot summer seasons and long, cold winters, and with labor scarce and high, it is not believed that artificial reforestation could be carried out for less than a minimum of $25 per

[5] "The Forests of Alaska." H. S. Graves, The Timberman, April, 1916.

acre. With millions of acres of burned and deunded forest land in interior Alaska, artificial reforestation would therefore require the expenditure of many millions of dollars. Moreover the climatic conditions are such that the chances of successful planting are extremely doubtful. Every indication would therefore lead to the conclusion that artificial reforestation in interior Alaska is entirely impracticable.

The sure way to provide a fuel and lumber supply for interior Alaska's present and future needs is to keep fire out of the forests that nature has already grown there. Under Alaskan conditions the best way to reforest is by preventing forest fires.

As a national duty it is imperative for the federal government, the owner of the lands involved, in cooperation with the Territory of Alaska and its residents, not only to stop forest fires, but to keep fire out of the interior forests in the future. The prevention of forest fires is therefore essential, and is more effective for a future timber supply than the actual suppression of fires that start. With a sparse population, immense distances to cover, and trails and roads few and far between, the fighting of forest fires after they start is an extremely difficult matter, and in many cases impossible; the best way to fight forest fires in interior Alaska is not to let them get started.

FACTS TO BE FACED

In suggesting any plan for the protection from fire of the forests of interior Alaska certain fundamental facts of human nature and Alaskan conditions must be recognized. Briefly these are:

1. The interior of Alaska has a sparse and scattered population, living largely under pioneer conditions and with the pioneer's point of view regarding natural resources, much as most of the western States were 25 years ago.

2. This being the case, the protection of the forests from fire must come through an awakened public sentiment. The pioneer population must be brought to realize that it is to their immediate interest, as well as that of succeeding generations, to use but also to protect from criminal neglect and waste a natural resource without which prosperity cannot long remain in any country.

3. In short, the prevention of forest fires must be driven home as well as the suppression of them after they are started, for the interior population is insufficient or too widely scattered to provide an effective suppression force in the ordinary case.

4. To remedy the situation and to fix clearly the responsibility there should be on the ground a small protective organization; this to consist of a forest supervisor with a force of forest rangers and patrolmen, in touch with public sentiment, to the end that the need for forest protection may be brought home. The mere presence of such an organization in the country will help in prevention.

5. The duties of this organization should be essentially fire prevention and fire patrol, rather than fire suppression, though the men should extinguish all fires in their respective districts wherever it is possible to do so. Under interior Alaska conditions it is not believed possible to secure a sufficient force of men to put out all forest fires that start; it is believed entirely possible and feasible to arouse public sentiment to the point where the large majority of the population will do their utmost to prevent forest fires. No plan of protection can succeed without the support of the local people.

6. Full and hearty cooperation in the work of bringing forest fire prevention before the public by existing Government agencies in the interior of Alaska is imperative; until this is brought about all efforts to secure public support are futile. Such agencies are: Alaska Engineering Commission, Alaska Road Commission, U. S. Land Office, State Relations Service, U. S. Bureau of Education, U. S. Signal Corps, U. S. Game Wardens, Federal Courts, Territorial Courts and Officers, U. S. Marshals.

ORGANIZATION THAT SHOULD BE RESPONSIBLE FOR FOREST PROTECTION

Since the Forest Service of the Department of Agriculture is the Government agency charged by Federal law with the protection and administration of 180,000,000 acres of forest lands in the United States, Alaska and Porto Rico, it would seem logical that this Service should have supervision of the protection from fire of the interior forests of Alaska, by reason of its 17 years' experience in handling government forest lands. The Forest Service has already a district forest organization in Alaska handling the 20,000,000 acres of National Forest lands along the coast. The protection of forested lands of the interior would therefore be work which this organization is qualified to handle. The interior forest should not be withdrawn from entry for National Forest purposes, nor included within a National Forest, nor should their existing status be changed in any way, other than that their protection from fire should be delegated to the Government service whose special function is the protection and administration of Federal forest lands.

THE STAND GRAPH AS A MEANS OF REGULATING THE CUT IN SELECTION FOREST [1]

By A. B. Recknagel

Professor of Forest Management, Cornell University

A normal forest has three attributes: Normal increment, normal age-classes in size and distribution, and normal growing stock. The first and the last of these are as easily ascertained for selection forest as for the even-aged forest, although current annual increment usually takes the place of mean annual increment.

There remains the distribution of age-classes, which is such a powerful help in regulating the cut in even-aged forest. Hitherto no substitute has been found for this in selection forest. True, the distribution of diameter classes, as expressed in the stand table and the stock table, approximates for selection forest what the table of age-class distribution does for even-aged forest, but the latter is easily grasped and made into a diagram,[2] which shows at a glance the relation of actual to normal distribution of the age-classes and, by successive entries, the approach toward normality under management.

Something like this is needed for the selection forest and the stand graph is the best apparent means to accomplish this. Woolsey [3] points out the use of the stand graph in France and gives illustrations thereof. By a stand graph is meant a plotted curve with the horizontal scale representing diameter (breast high), and the vertical scale representing the number of trees per average acre. If the vertical scale represents volume of trees per average acre the result is a *stock graph.*

A combined stand and stock graph has been prepared for a tract in the western Adirondacks. The irregularities in diameter class distribution are due to the vagaries of student measurements and a marked partiality towards even inch diameters. If sufficient care is used and a large enough area covered, a smooth curve will result. This curve accurately presents the diameter class distribution and as

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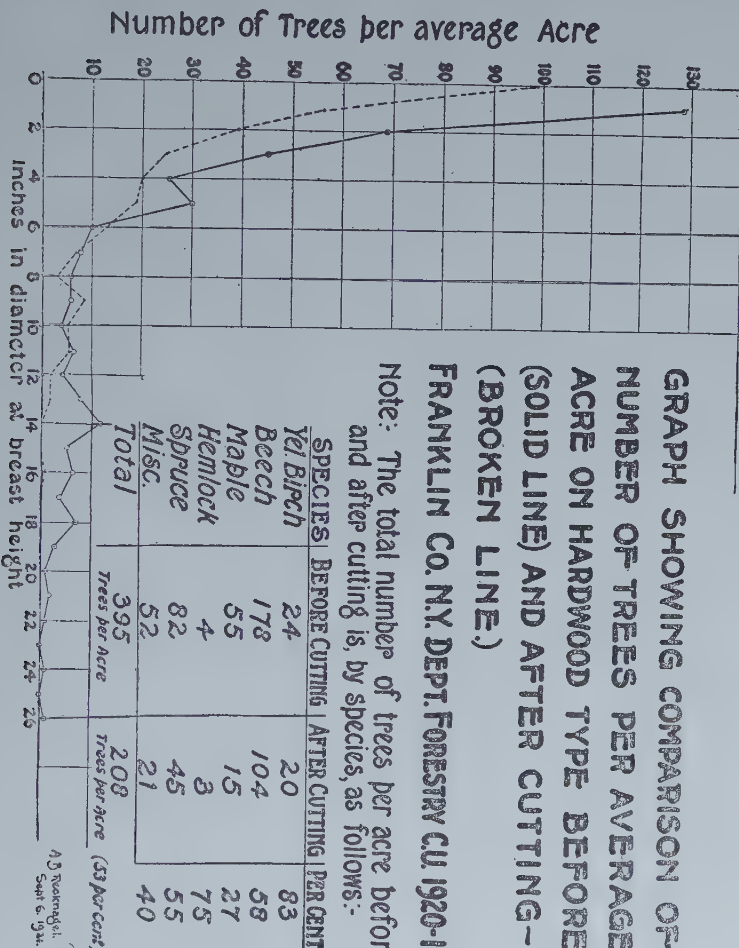
[1] Paper presented at the annual meeting of the Society of American Foresters, Toronto, Dec. 28, 1921.

[2] See figure 25 in Recknagel and Bentley: "Forest Management," and diagram D in Recknagel: "Forest Working Plans," 2d edit.

[3] Woolsey, T. S., Jr., "Studies in French Forestry," "Stand Graphics," pp. 214-217; also figs. 19 (a) and (b).

our management progresses, we may, conceivably, have normal curves for each type and region wherewith to compare the actual curves for



a given forest, just as is now done in diagrams of age-class distribution. Stand and stock graphs are also of help in fixing diameter limits and in other silvicultural determinations.

There is, however, a present and much greater utility for the stand graph and that is as a means of regulating the cut in selection forest. The selection forest has always presented difficulties in regulating the

cut—which, because there are no definite age-classes, must be chiefly by volume rather than by area.[4]

The factor of *mortality*—due to windfall and destruction in logging—has seldom been given proper weight in these volumetric determinations. To assume that, in cutting to a 12-inch diameter limit, for example, all the 11-inch trees will live and grow, all the 10-inch, 9-inch, 8-inch and so on, is a serious error. Yet this method precisely was followed in the early working plans of the Forest Service and the calculations showed the added volume of the smaller diameter classes by decades until a "second cut equal to the first" was obtained.

Fernow[5] first pointed out the fallacy in such an assumption when he said: "And especially with this method caution is necessary, as it is based upon the assumption, probably not often correct, that reproduction will take place, and that younger age classes in sufficient number and amount are in existence to take the place of the older; when, as is often the case in the virgin uncut woods, most of the trees are of exploitable size, this assumption and with it the method of regulating the budget fails entirely." Nevertheless, the actual diminution in number of trees due to destruction in logging has seldom been ascertained and put to practical use in regulating the cut.

How great this reduction in numbers of the smaller diameter classes may be is shown by the measurement before cutting, in 1920, of a typical acre of hardwood land in the Adirondacks and its remeasurement the following year. The accompanying graph and table shows the results. This presents two stand graphs—before and after cutting—and the spread between the two curves shows the destruction in logging of the small stuff below the merchantable diameter of approximately 12 inches in the hardwoods.

The stand graph indicates a heavy loss, through logging, in the smaller diameter classes on which we customarily count to replace the forest. *In regulating the cut in selection forest this reduction in numbers must be taken into account* and can be done most readily by ascertaining the reduction factor based upon the measurement before and after cutting of a sufficiently large area.

Tentative figures based upon such a study on hardwood land in the Adirondacks are shown in the graph presented by Professor Spring. By diameter classes the reduction factor is as follows:

[4] See "Correlation of Silvicultural Methods and Methods of Determining the Cut," Recknagel: "Forest Working Plans," 2d edit., pp. 126-128.
[5] "Economics of Forestry," 2d edit., pp. 219-220.

D. B. H., ins.	Reduction factor	D. B. H., ins.	Reduction factor
4	.41	11	.54
5	.48	12	.45
6	.54	13	.33
7	.43	14	.26
8	.60	15	.26
9	.46	16	.33
10	.48		

This, of course, is for all the species. When it comes to regulating the cut for an individual species, the reduction factor must be figured for that species. It can then be applied directly in the Swiss Method[6] as the following example shows. This is worked out in 1921 for hard maple for a tract of 160 acres of hardwood land near Tupper Lake in the Adirondacks. Volumes were taken down to 9 inches d. b. h. only; the diameter limit is fixed at 12 inches (trees of this size to be cut), and the "maturity limit" at 16 inches (no trees to be raised to over this size). The calculations then proceed:

STEP 1.

D. B. H., inches	Volume before cutting, board feet on 160 acres	Reduction factor due to logging	Reduced volume after logging, board feet	Current annual increment	
				Per cent	Board feet
9	7,022	.86	6,038.92	.0262	158.21
10	7,978	.87	6,940.86	.0250	173.52
11	13,932	.87	12,120.84	.0231	279.99
			Total Xi	....	611.72

STEP 2.

	Swiss method with reduction	Swiss method without reduction
	Board feet	*Board feet*
Xi	611.72	705.26
Yi	3067.68	3067.68
Xi+Yi	3679.40	3772.94
$cc=\frac{Y}{Xi+Yi}$	$\frac{176272}{3679.40}=48$ years	$\frac{176272}{3772.94}=46.72$ years

[6] Recknagel and Bentley: "Forest Management," Art. 101, p. 152. Recknagel: "Forest Working Plans," 2d edit., pp. 74-77. See also For. Quart., Vol. XIV, pp. 260-267 and Jour. For., Vol. XV, pp. 564-573.

STEP 3.

	Swiss method with reduction	Swiss method without reduction
Allowed cut $= \frac{Y+Z}{cc}$	*Board feet* $\frac{176272+419168}{48}$ $=\frac{595440}{48}$ $=$ 12,405 bd. ft. allowed annual cut	*Board feet* $\frac{176272+419168}{46.72}$ $=\frac{595440}{46.72}$ $=$ 12,750 board feet allowed annual cut.

NOTE: The following symbols are used in these calculations:

X = the diameters below the diameter limit; Xi the current increment thereof.

Y = the diameters between the diameter limit and the "maturity limit" beyond which size it is not planned to grow the second crop.

Z = the diameters beyond the maturity limit—i.e., over-mature stock.

cc = the cutting cycle. i = the current annual increment.

The reduction factor is of equal importance in regulating the cut by other volumetric methods, but can not be gone into here.

CONCLUSION

Many of our forests are of the selection form and are apt to remain so even under management. For selection forest we need a determination of diameter class distribution similar to the age-class distribution in even-aged forest. This can be expressed diagrammatically by a stand graph and ultimately normal stand graphs can be constructed wherewith to compare the actual stand. Stock graphs can be similarly treated. Of direct present importance is the stand graph before and after cutting as furnishing reduction factors showing the loss due to destruction of the smaller trees in logging under present commercial practices. This reduction factor can be applied in figuring the volumes remaining of the trees of small diameters and the increment thereon following the cutting. In this way the stand graph is of direct utility in regulating the cut in selection forest by any of the volumetric methods. Further studies are needed to furnish reliable reduction factors applicable to a given type in a given forest region. Careful strip surveys or sample plots will furnish the needed data.

RELATION OF CROWN SIZE AND CHARACTER TO RATE OF GROWTH AND RESPONSE TO CUTTING IN WESTERN YELLOW PINE.

By Duncan Dunning

U. S. Forest Service

In selecting trees to be left as reserves for increased growth in cutting operations and in thinnings, it is necessary to have some means of readily approximating their rate of growth and the probable effect of release by cutting. Perhaps if the inherent possibilities of our species were as well known as those of most European species, it would only be necessary to know the age and duration and degree of suppression. In our mixed all-age stands it is, of course, impracticable to determine these facts accurately for each tree, and reliance must be put on readily determined external indications.

The generally accepted crown classes based on position in the canopy, the usual guide in thinning, have little value in mixed all-aged stands where they do not necessarily indicate relative rates of growth. In such stands small young thrifty trees may be superior in vigor or rate of growth though far below the upper crown canopy. In mixed stands an incense cedar, for example, may be considerably shorter than surrounding pines of the same age, but due to greater tolerance may retain a large dense crown and be superior in rate of growth. In mixed stands one species, though dominant as to position and of the same age as associates, may show inferior growth due to adverse local soil conditions or approach to its limits of distribution. It is quite possible for individual trees to be inherently lacking in vigor and though given complete illumination and unlimted root space never to attain superiority in rate of growth. Relative vigor is not determined by degree of illumination alone.

On a 24-acre sample plot on the Plumas National Forest there are 366 yellow pines over 12 inches in diameter of which 318 are classified as dominant. Segregating these 318 dominants into two groups, one composed of trees with crowns of average size or larger and pointed tops, was found to be growing in basal area at the rate of 1.22 per cent annually, while the second group composed of trees with smaller than average crowns and round, flat or dead tops, was growing at the rate of only 0.42 per cent annually. On the same area trees between 12

and 18 inches in diameter, called intermediate and suppressed, which had crowns of normal size or larger and pointed tops, were growing at the rate of 1.37 per cent annually while trees of the same size called dominants, but having smaller than average crowns and round, flat or dead tops grew only 0.96 per cent annually.

The inadequacy of strictly interpreted rules for the orthodox crown classification when applied to western mixed selection stands in which a large majority of the trees are approaching or are beyond maturity has resulted in a tendency on the part of some foresters to group the trees more according to vigor than to mere position in the crown canopy. There are certain factors of external appearance readily observed for each tree, such as size, density and color of crown, shape of top, character of bark, etc., which are known to reflect age and vigor.

It is well known that rate of growth for a given site and age class is directly proportional to crown area. A very clear demonstration of this was made at the Austrian Experiment Station as described by Zederbauer, in which Douglas fir and other species are subjected to prunings removing one-third and one-half of the crown area. In the first case growth was reduced 48 to 64 per cent, and in the latter case 70 to 80 per cent. Similar results have been destroyed by fire. The need of some supplementary groups in addition to crown classes was recognized by Heck, who proposed in 1904 a free or individualized method of thinning (*freie durchforstung*) based on crown classes supplemented by a number of stem classes. Calculations showed that his Group A trees, corresponding to the *elite* of French foresters, grew more rapidly and produced better wood than the other groups. While it goes without saying that in all methods of cutting or thinning the trees of best bole form are favored because of the better quality of wood produced, so far as known, there has never been any attempt in this country to group trees according to combinations of external crown features.

It is hoped by presentation of the following data to demonstrate to what degree such grouping may be relied upon in marking western yellow pine. The data were obtained from permanent sample plots on timber sale areas on the Shasta, Tahoe, Plumas, and Sierra National Forests in California, covering ten years or more. All these sale areas represent the early type of light selection cuttings in mixed stands, except that on the Tahoe, which was a very similar shelterwood cutting. On these sample plots each tree is numbered and the diam-

eters are measured with a tape and the heights with a Klaussner hypsometer at 5-year intervals. A description of each tree is recorded with the other notes. Besides the actual measurements, the descriptions include the following points:

1. Dominance classes, as isolated, dominant, codominant, intermediate, or suppressed.
2. Crown width, as wide, medium, or narrow.
3. Crown length, as long, medium, or short.
4. Form of top, as pointed, round, or flat; spiked top or broken top.
5. Apparent vigor, as indicated by density and color of foliage, form of top, appearance of bark, and presence or absence of pathological agencies—as vigorous, moderately vigorous, or of poor vigor.

It is evident that the description of a tree, except perhaps as to form of top, is subject to variations in the opinion of the observer. However, in many cases considered where the same trees were described by different men, few important differences occurred. In most cases these distinctions can be readily made in marking.

The following groups have been made by assembling the trees according to combinations of the above factors:

Group 1—Mostly dominants, with some codominant and isolated trees with vigorous appearance, pointed tops, and such combinations of crown widths and length as constitute crowns of average size or larger, as wide-long, medium-long, narrow-long, wide-medium, and medium-medium, or briefly, large crowned, thrifty dominants.

Group 2—Similar to the above as to crown class, vigor and form of top, but with smaller than average crowns, described as narrow-short, medium-short, wide-short, or narrow-medium; small crowned, thrifty dominants.

Group 3—Mostly dominants, with some codominant and isolated trees, with the appearance of poor vigor, flat, round, or dead tops, and crowns of average size or larger; large crowned dominants of poor vigor.

Group 4—Similar to Group 3, but with smaller than average crowns; small crowned dominants of poor vigor.

Suppressed and intermediate trees have been omitted from most of the calculations because of scant data, nearly all such trees being below the size limits affected by markings. Western yellow pine only is considered.

To indicate first the difference in rate of growth for the above groups, data are summarized in Table 1 for 349 trees from the Plumas Forest. The figures represent the periodic annual growth per cent in basal area from 1911 to 1920, following cutting.

TABLE 1.—*Periodic Annual Basal Area Growth Per Cent. 1911-1920. Plumas.*

Group	Diameter classes										Total		Per cent deviation from average
	12-17		18-23		24-29		30-35		36 plus				
	Number of trees	Growth per cent	Number of trees	Growth per cent	Number of trees	Growth per cent	Number of trees	Growth per cent	Number of trees	Growth per cent	Number of trees	Growth per cent	
1	75	1.94	82	1.34	32	1.00	17	0.73	3	0.48	209	1.22	+56.3
2	27	1.09	10	0.75	2	0.92	....	....	....	....	39	0.95	+21.8
3	8	1.63	11	1.13	24	0.52	23	0.42	11	0.43	77	0.55	—29.5
4	12	0.96	1	0.21	5	0.50	5	0.28	1	0	24	0.42	—46.1
Average	122	1.40	104	0.86	63	0.73	45	0.48	15	0.30	349	0.78	....
Ratio 1 to 4..	....	2.02	....	6.38	....	2.00	....	3.84	....	....	....	3.44	....

It will be seen that for all diameter classes the trees with crowns of average size or larger (Groups 1 and 3), have grown much more rapidly than the trees with smaller than average crowns (Groups 2 and 4). For all diameter classes combined Group 1 trees have grown 28.4 per cent more rapidly than Group 2 trees and Group 3 trees have grown 31.0 per cent more rapidly than Group 4 trees.

If trees with pointed tops be compared with trees having round, flat, or injured tops, Group 1 with 3, and Group 2 with 4, dominance class and crown size remaining constant, still greater differences appear. Group 1 trees have grown 121 per cent more rapidly than Group 3 trees and Group 2 trees have grown 126 per cent more rapidly than Group 4 trees. That is to say, a general appearance of vigor is four times as important as crown size alone in selecting trees to leave for growth.

Considering extreme differences in rate of growth between the thrifty large crowned trees of Group 1 and the small crowned trees of poor vigor in Group 4, it is seen that Group 1 trees grew 3.44 times as fast as Group 4 trees.

If growth be expressed in terms of volume in cubic feet, as shown in Table 2 below, the same relations are found to hold, but as would be expected the contrast between trees with pointed tops and trees with round, flat, or injured tops is greater, as shown by the last column, since height enters into volume calculations. In volume Group 1 trees grew 3.23 times as fast as Group 4 trees.

TABLE 2.—*Periodic Annual Volume Growth Per Cent. 1911-1920. Plumas. Cubic Feet.*

Group	Number of trees	Growth per cent	Deviation per cent from average
1	209	1.68	+64.7
2	39	1.26	+23.5
3	77	0.63	—38.3
4	24	0.52	—49.1
Average	.....	1.02	......

That the large class of trees with narrow-long crowns properly belongs in the large-crowned groups was determined by summarizing such trees separately. Such trees grow near the maximum rate for the large crowned groups.

The Plumas plot from which the above data were taken represents a rather poor sit. On the basis of five site classes it would be about Site III for yellow pine in California, the mature dominants being about 120 feet in height. If a better site is considered the differences due to crown variation are found to be accentuated. Table 3 below presents data from 41 trees on the Sierra plot which represents a good Site II for yellow pine. The trees are 12 to 36 inches in d. b. h. and the distribution by diameter classes is about the same for both groups.

TABLE 3.—*Periodic Annual Growth Per Cent in Basal Area. 1911-1920. Sierra.*

Group	Number of trees	Growth per cent	Deviation per cent of average
1	29	1.83	+28.8
2	12	1.01	—28.8

The trees with large crowns have grown 82 per cent more rapidly than the trees with small crowns, as compared to about 30 per cent on the Plumas for similar groups. The total deviation from the average is 58 per cent for the Sierra as compared with 29 per cent for the same groups on the Plumas.

These results concern only the quantity of wood produced. It is, of course, evident that trees with excessively large crowns, although growing at a rapid rate, may not be desirable trees to leave because of the poor quality of the wood produced.

RESPONSE TO CUTTING

Age, duration of and degree of suppression are usually considered the principal factors determining the ability of a tree to respond to cutting, and since these facts cannot be readily determined in the stands under consideration, we must again resort to outward appearances to estimate the probable response that each tree will make after release by cutting. The following data are from increment cores from 231 trees on the Forests mentioned above. The figures in Table 4 represent the periodic growth per cent in basal area by 5-year intervals before and after cutting. The trees have been assembled in two groups. Group 1 corresponds to Group 1 above, and consists of dominant, codominant or isolated trees with pointed tops, vigorous appearance and crowns of normal size or larger. Group 2 is composed

of all other inferior trees, nearly all of which are also dominant, codominant or isolated as to position, but with round, flat or injured tops, poor vigor and smaller than average crowns. A few suppressed and intermediate trees with various sized crowns are also included in Group 2.

TABLE 4—*Response to Cutting Expressed in Periodic Basal Area Growth Per Cent.*

Forest	Group	Number of trees	Years: Before cutting 10	Years: Before cutting 5	Years: After cutting 5	Years: After cutting 10	Years: After cutting 15	Average before	Average after	Per cent acceleration
			[1] 106	101	101	83		104	91	
Shasta	1	20	6.46	4.77	5.90	6.24	......	5.61	6.07	8.2
	2	34	3.14	2.37	2.93	3.41	.....	2.75	3.17	14.3
			139	141	146	94		140	119	
Plumas	1	51	8.54	8.58	9.84	8.64	......	8.56	9.24	8.0
	2	39	3.57	3.56	3.99	4.46	......	3.56	4.22	18.4
			142	166	164	103		154	139	
Tahoe	1	31	5.64	6.31	7.73	7.76	......	5.97	7.74	29.5
	2	36	2.33	2.37	2.93	3.83	......	2.35	3.38	44.0
			147	185	195	155	78	164	135	
Sierra	1	28	13.04	12.56	19.82	28.15	18.39	12.80	22.18	73.1
	2	12	5.28	4.40	6.72	11.20	10.31	4.84	9.41	94.5

[1] Per cent by which Group 1 exceeds Group 2.

As in the previous cases considered there is seen to be a striking contrast in rate of growth between Group 1 and Group 2 trees on all Forests. Prior to cutting, Group 1 trees grew grew from about 100 per cent to 185 per cent more rapidly than Group 2 trees. During the second and third periods after cutting, however, this difference is seen to have decreased. This indicates what the last column of the table clearly shows that the poorer Group 2 trees, while still growing at a much slower rate, have shown a greater relative response to cutting than the better Group 1 trees.

This is at first rather surprising. The thought is immediately suggested that the poorer trees are younger and might be expected to respond better to cutting. Just the reverse of this, however, was found to be true. While total age determinations in most cases cannot be made because of the large size of the trees, where this was possible Group 2 trees were found to be uniformly older than Group 1 trees of corresponding sizes. The dominant thrifty trees were probably growing near the potential rate for the species on the site before cutting, while the Group 2 trees were growing far below that rate. Cutting resulted in a relatively greater improvement in the environment of the latter group which has consequently shown a relatively greater acceleration than the former group.

Referring again to Table 4 it will be seen that the percentage of acceleration increases progressively from the Shasta to the Sierra. The Shasta plot represents a poor quality Site III, the Plumas and Tahoe somewhat better qualities of Site III and the Sierra a good Site II. It is evident that all classes of trees show a greater response to cutting on good than on poor sites.

Promptness of response is found to be closely related to size of crown. It is to be expected that trees with large crowns and a large number of growing points from which to construct crowns area could more readily avail themselves of increased light, moisture and soil area, resulting from the removal of associates and of stored reserves of food material than trees with small crowns as a result of long suppression or other causes.

Considering first the Sierra trees it is seen from the following table that 45 per cent responded the first year after cutting, 15 per cent in the second year and 17.5 per cent in the third, or about 78 per cent within three years after cutting. Of the 31 trees which responded within 3 years of cutting 84 per cent had larger than average crowns. Of the 9 trees requiring 4 years or more to respond, 67 per cent had smaller than average crowns. Expressed in another way, of the 29 trees which had large crowns 18, or 62 per cent, responded the season following cutting, while of the 11 with small crowns only 1, or 9 per cent responded the first year.

If we consider the poorer Tahoe site, response of all classes of trees is seen to be delayed. Only four or 6 per cent, responded the first year; thirteen, or 19 per cent, responded the the second season, while thirty-nine, or 58 per cent, responded the third season. Of the

TABLE 5.—*Number and Per Cent of Trees Responding in Various Years after Cutting.*

Forest or crown group	Years after cutting																	
	1		2		3		4		5		6		7		10		No response	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Sierra..........	18	45.0	6	15.0	7	17.5	4	10.0	1	2.5	......	......	1	2.5	1	2.5	2	5.0
1. Large........	17	......	6	......	3	......	3	......	......	......	......	......	......	......	......	......	......	......
2. Small........	1	......	......	......	4	......	1	......	1	......	......	......	1	......	1	......	2	......
Tahoe..........	4	6.0	13	19.3	39	58.2	4	6.0	......	......	1	1.5	......	......	......	......	6	9.0
1. Large.......	4	......	11	......	33	......	2	......	......	......	......	......	......	......	......	......	......	......
2. Small.......	......	......	2	......	6	......	2	......	......	......	1	......	......	......	......	......	6	......

fifty-six trees responding in 3 years or less, forty-eight, or 85 per cent, had large crowns and only eight, or 15 per cent, had small crowns. Six trees showed no response to cutting or decreased in rate of growth, and while half of these had large crowns, the tops were round, flat or dead—indicating old trees of poor vigor. Of the fifty-three trees with large crowns 90 per cent responded within 3 years while only 57 per cent of the small crowned trees responded in the same period.

As to duration of response there seems to be no clear correlation with size of crown. From examination of cores from six cuttings made at different dates on the Sierra the average time to reach the maximum acceleration after cutting was 9 years, the average from the time response started to the time of reaching the maximum being 7 years. Data from cuttings at different dates eliminate the possibility of the maximum acceleration occurring for all trees in the same season which would cause doubt as to whether precipitation was not the controlling factor. Comparison with weather data from the nearest stations indicates that the maximum rate was not reached with any degree of regularity in years of heavy precipitation.

On the poorer Tahoe site, while the start of response is delayed, the maximum acceleration seems to be reached sooner than on the better Sierra site. On the Tahoe 69 per cent of the trees attained the maximum rate within 6 years after cutting. Since most of these trees required 3 years to respond, only 3 years elapsed on the average between the start and maximum rate of acceleration. There is a slight indication that the large crowned trees reach the maximum rate sooner than the small crowned trees, as might be expected, since when the stand is opened trees of the lower canopy with small crowns would require some time to increase their leaf area.

The total length of time for the effects of cutting to disappear cannot be determined from present data, because of the recent dates of most of the cuttings. Ten to fifteen years after cutting nearly all the trees which have responded are still growing more rapidly than prior to cutting although the rate is declining. This is also true of dominant trees on areas cut over as long ago as 1880 and 1898 on the Sierra.

It is recognized that in attempting to determine the duration and amount of accelerated growth it is difficult to weigh the varying effects of soil changes, encroaching vegetation and closing of the crown canopy which follows cutting, as well as to varying degrees in which cutting increased illumination.

To summarize briefly it is desired to emphasize the following points:

Present crown classes as applied to all-aged or mixed stands do not represent vigor classes, or relative rates of growth as required in marking.

It is believed that in such stands a grouping of trees by combinations of readily observed external features of which position in the crown canopy is only one, can be made to indicate more accurately the relative vigor of trees than the present grouping by crown classes alone.

Trees with crowns of normal size or larger grow faster than trees of the same diameter and crown class with smaller than average crowns by from 30 to 100 per cent or more.

Trees with a general appearance of vigor produced by dense, dark green foliage, pointed tops and dark rough bark are usually growing 100 to 200 per cent more rapidly than trees of the same size and crown class with scanty pale foliage, flat or dead tops, and smooth yellow bark.

Trees with large pointed crowns responds more promptly to release by cutting than trees with small badly formed crowns.

Trees growing at a slow rate as indicated by small crowns, flat tops, etc., may show a greater relative response to cutting than trees of vigorous appearance but the absolute rate attained is seldom as high as that of the latter trees.

The present data show no clear relation between crown size and the duration of enhanced growth, or the time to reach the maximum acceleration after cutting. The maximum rate of current growth is usually reached 6 to 9 years after cutting, depending on site, probably sooner on poor than on good sites, and sooner by trees with large, well-formed crowns, than by trees with small badly formed crowns. Vigorous western yellow pine trees in some cases still show the effects of release by cuttings made over 30 years ago.

THE USE OF DIAMETER AGE CHARTS IN YIELD STUDIES

By Herman Krauch

U. S. Forest Service

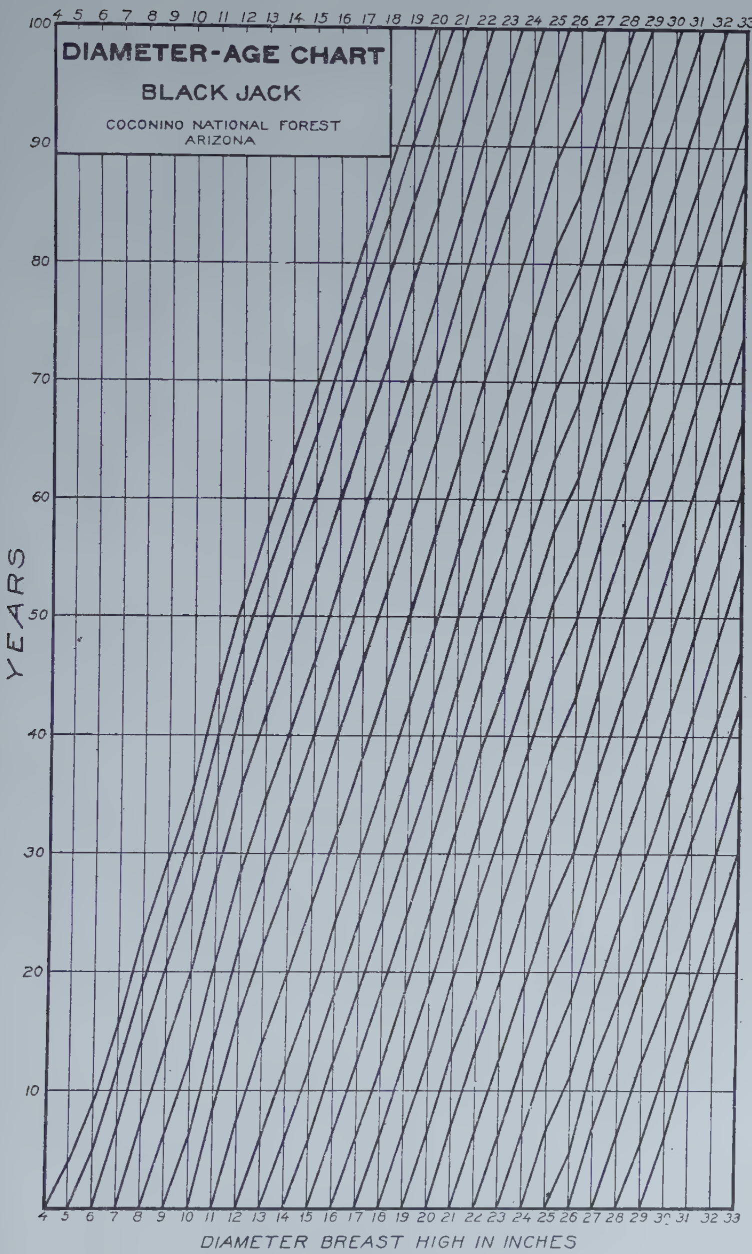
In determining yield it is generally desired to know how long it will take trees to grow to merchantable size or how large they will be at the end of a certain period. An uneven aged forest, such as western yellow pine, is composed of many diameter classes and it is therefore necessary to make growth calculations for each class separately. To facilitate such calculations it occurred to the writer that an alinement chart would be of great assistance.[1] The accompanying figure is an example of such a chart. It is based on the growth of black jack on cut-over stands in the western yellow pine type in Arizona. The values are mathematical averages which have not been curved. This accounts for the slight irregularity of lines shown on the chart.

Let us assume that it is desired to show how long it will make trees to grow to merchantable size or how large they will be, say in 50 years. This information is readily obtained from the chart. Following is a tabulation of such values:

Diameter class	Diameter in 50 years	Time required to grow to 20 inches d. b. h.	Diameter class	Diameter in 50 years	Time required to grow to 20 inches d. b. h.
4	11.8	100	12	20.2	49
5	12.4	96.0	13	21.0	43
6	13.2	91.5	14	22.0	37
7	14.4	84.5	15	22.9	31
8	15.6	77.5	16	23.9	25
9	16.6	71.0	17	24.9	19
10	17.7	65.0	18	26.1	13
11	19.0	56.5	19	27.0	6
			20	28.0	..

Having determined how large the present trees will be in 50 years, it is a simple matter to compute the increase in volume of a whole stand. And, since only timber of merchantable size would probably

[1] Similar charts have already been made for volume tables. See article in Journal of Forestry, Vol. XVII, No. 8, December, 1920.


DIAMETER-AGE CHART
BLACK JACK
COCONINO NATIONAL FOREST
ARIZONA
YEARS
DIAMETER BREAST HIGH IN INCHES
100 90 80 70 60 50 40 30 20 10
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33

be cut at the end of 50 years, the table shows that trees below 11 feet d.b.h. will not have reached merchantability by that time. That portion of the stand between 4 feet and 10 feet d.b.h. is therefore at once eliminated from the calculation of yield for the period involved. In calculating the yield for the balance of the stand, allowance must be made, of course, for mortality occurring during the 50-year period. What this would be is difficult to determine at present because there are not sufficient data available to form the basis of such calculations.

The foregoing discussion is merely an example of how diameter age charts might be used and this article has been presented with that object in view. As a ready reference for information regarding the growth of trees a diameter age chart ought to serve a useful purpose.

SEEDLING VS. TRANSPLANTED STOCK FOR FOREST PLANTING

By B. H. Paul

Forest Products Laboratory, Madison, Wis.

The question of using seedlings or transplants in making forest plantations is a matter of very great importance, and one which is often raised when forest planting is considered, on account of the great difference in the cost of making a plantation with seedlings or transplants. With the idea of determining in a general way the success which had been obtained by persons planting seedlings throughout New York State, a questionnaire was prepared and mailed to thirty-five persons who had secured considerable quantities of seedling stock from the nurseries of the New York State Conservation Commission. Reports were received upon thirty of these questionnaires covering a total of 797,500 trees, the number originally planted. The species included are principally white pine with some Scotch pine, red pine, and Norway spruce. The making of the various plantations covers a period of approximately ten years beginning with the year 1909.

The questionnaire contained six questions. The questions and the general summary of the answers given to each question are presented below. The answers given, while not conclusive, will serve to give an idea of the average conditions under which seedlings have failed to do well, and where they have succeeded satisfactorily.

Question 1.—What percentage of two-year seedlings planted by you have lived and made satisfactory growth?

The answers to this question are grouped according to the percentage now living of the number of trees planted as follows:

Original number of trees planted	*Percentage living*
362,000	Less than 50 per cent
131,000	51 to 75 per cent
304,500	75 per cent and more

A careful examination of the reports indicates that in cases where the loss was more than 50 per cent, the soil type was usually reported as sandy and ranging from a gravelly sand to a sandy loam. The condition of vegetation on these lands indicates that with two

exceptions the natural growth of grass, weeds, and other vegetation was very light, and not sufficient to furnish much protection in the way of shade to the young trees. In two cases where the trees were planted on a sandy loam soil, there was a rather heavy growth of grass and weeds. A loss of 50 per cent also occurred among trees that were used for underplanting in a hardwood forest situated in Orange and Rockland counties where the greater part of the original forest had been destroyed by the chestnut blight. The report states that subsequent removal of the hardwoods was contemplated at the time of planting but this was not done, and it is likely that the loss in this case was partly due to too much shading. Where from 50 to 75 per cent of the trees succeeded, they were reported as having been planted on sand, sandy loam, and clay loam soils, and these plantations were made either on old meadows or pastures.

Plantations in which a loss of less than 25 per cent occurred were made on land ranging from a sandy to a clay loam soil, most of them being either on loam or sandy loam, and the condition of vegetation present being in several cases old meadows and pastures, and in other cases light sand with grass and bracken, and in one case the land was prepared for the trees by cultivation.

Question 2.—Have any two-year seedlings done well when planted in old meadows or any situations where there was considerable vegetation upon the ground?

In replying to question two, there were thirteen answers in the affirmative, five in the negative, and three reported that trees were planted where there was scanty vegetation; one reported that trees would not do well unless the soil was prepared by removal of vegetation, and another reported that the more vegetation the better.

While these statements are more or less contradictory, it is evident that seedlings will succeed on land of the old meadow and pasture type when there is a sufficient quantity of moisture and not enough vegetation to smother the young trees.

Question 3.—Have you found it necessary to replant any of the trees originally planted with seedlings?

In thirteen out of thirty cases replanting had been done, and in three other cases, statements were made that replanting ought to have been done. In fourteen plantations it was stated that replanting was not necessary.

Question 4.—In case you have used both seedlings and transplants in reforesting, which do you prefer for planting under all conditions, taking into consideration also the difference in cost, seedlings at $1.50 to $2 per thousand, and transplants at $3.50 and $5.50 per thousand?

Replies to this question show that fifteen of the thirty parties replying prefer transplants. The records show that all of these persons have planted both seedlings and transplants and, therefore, they are in a position to state their preference on a basis of their experience.

Six reported that they prefer seedlings but only two of this number have used transplants. Another reported that seedlings are satisfactory.

Question 5.—State any particular reason why you give preference to seedlings or transplants?

Those preferring transplants stated that transplants will stand more dry weather, are better suited to all conditions, would grow faster, more of them live, and that transplants can better withstand competing vegetation.

Those preferring seedlings based their preference on statements that seedlings were more apt to live, were cheaper, used less moisture, and would overtake transplants.

Question 6.—State conditions of vegetation where seedlings have done best?

Replies to question six show that in sixteen cases optimum conditions for seedlings existed on old meadow or pasture land; in five cases, among light vegetation; in two cases, cultivated land free from grass; in two cases where they were shaded by vegetation; in one case where the ground was either bare or with very light sod; one reported vegetation as injurious to seedlings.

The conclusions which may be drawn from examination of these various reports indicate that on sandy soils which are unretentive of moisture, seedlings are benefited by the presence of natural vegetation; that on loam soils which are capable of retaining the necessary moisture, the presence of natural vegetation in small amounts would probably not have any very great bearing upon the success of plantation one way or the other, and that the presence of luxuriant growth of vegetation on the heavier soils will undoubtedly crowd out or smother a great number of the small seedling trees before they attain a size sufficient to compete successfully for growing space and sunlight.

FOREST MANAGEMENT IN THE REDWOOD REGION OF CALIFORNIA

By David T. Mason

Forest Engineer, Portland, Oregon

The redwood region of the northwest coast of California is one which is less familiar to foresters of the United States than are most other forest regions. This is probably because there are no National Forests in this region, and also because the region has been comparatively inaccessible. The redwood extends practically from the Oregon line to San Francisco in a narrow belt, usually less than twenty miles wide, close to the ocean. There is some redwood, but not a great quantity, south of San Francisco. The southerly end of the belt has already been largely exhausted.

The entire original redwood forest is estimated to have covered approximately 1,400,000 acres, of which 450,000 acres have already been cut over. The remaining stand of timber of the belt is estimated at 85 billion board feet, consisting of redwood, 85 per cent, together with Douglas fir, lowland fir, and Sitka spruce, making up the remainder. All of this timber is privately owner, except relatively small quantities owner by public institutions. The National Forests of northwest California do not extend into the redwood belt.

About 1902 some members of the Bureau of Forestry made an investigation of the redwood region and published a report. For many years after that foresters paid little or no attention to the region until within the last few years the forestry staff of the University of California has conducted some brief studies of rather a preliminary nature in the region.

The annual cut of redwood lumber is approximately 500 million board feet produced by about twenty different companies. Of these the Union Lumber Company has recently adopted the policy of managing its lands for the permanent production of crops of timber. The Pacific Lumber Company, the Hammond Lumber Company, the Little River Redwood Company, the Mendocino Lumber Company, and the Glen Blair Redwood Company have recently undertaken a serious study of

the possibilities of permanent forest management under the particular circumstances under which each of them operates. The Union Lumber Company is just beginning the work of preparing the working plan for putting its permanent forest management policy into effect. The other companies are having made a preliminary survey of the possibilities of forest management before deciding in what way they will manage their forest properties.

Although foresters have given some consideration to this region in the past, little work has been done here in comparison with any of the other important forest regions of the country. The first work to be done in dealing with the problems of redwood management includes the making of what may be called a regional survey in which it is proposed to assemble existing information with regard to redwood, to determine what are the problems which are still unsolved, and to set about the solution of these problems in order to arrive at the basic principles upon which redwood management must be based. It is known, for instance, that redwood reproduces well from sprouts and from root suckers; it does not reproduce well from seed; it grows very rapidly on favorable sites. But we do not yet know in sufficient detail just what may be expected from natural reproduction, just how fast redwood grows, etc. Beyond this general regional survey, it is necessary in the case of each company interested to determine roughly and in a preliminary way the possibilities of forest management under the circumstances affecting each of the companies.

The work now in process will, no doubt, be of some interest as it develops, because for the first time in the West a considerable group of operators (which produce approximately two-thirds of the redwood now being marketed) has either adopted forest management as a permanent policy, or are seriously considering doing so. It seems quite likely that within a year or two a large share of the redwood production will be cut from lands under permanent forest management. This seems the more likely because other companies than those mentioned above have indicated that they also are more or less interested in the matter of forest management. The redwood region is perhaps more favorable for forest management than any other in the West; it is therefore fitting that it should lead the way in developing private forest management in Western United States.

REVIEWS

Timber for the State. Bulletin 5, Wisconsin State Conservation Commission, January, 1922.

The Wisconsin Conservation Commission in an eight-page illustrated brochure, sets forth simply and interestingly the situation in Wisconsin as regards the State's future local timber supply, and outlines the steps necessary in the opinion of the present administration to meet the situation. Starting with the significant statement that, "The years . . . just passed has witnessed the first closing down of several . . . large sawmills that have operated for years in Wisconsin," and that, "Each sucessive year will bring similar occurrences," it is pointed out that while the removal of the forest has made possible Wisconsin's great agricultural development, wood is a basic raw material on which the State's agricultural and industrial system depends and that steps are necessary to perpetuate the local supply. Harvesting mature timber is advocated and past and present logging practices are defended on the ground of economic necessity, as is also the clearing of land for agricultural use. But, it is contended, all land should be kept "at work producing either food or forest crops," nor, it is stated, can we "afford to wait until the last tree is cut."

The requirements of the situation are given as protection from fire and grazing, fire protection being rated at 75 per cent of the forest replacement problem. Artificial reforestation, it is contended, is not economically feasible on a large scale nor necessary except as a last resort in the case of areas devasted by fire. Cutting so as to encourage natural regeneration is advocated instead, together with a revision of existing tax laws which will enable owners of second growth to hold it to maturity. A nominal annual tax on the productive value of the land is recommended.

While it is admitted that "there are millions of acres of rough, lean, hilly, low, or stony land in the State that can be made to yield large quantities of both hard and soft wood," it is contended that the bulk of "these lands are, or eventually will be parts of farms." Only on extensive "areas of poor sandy or rough lands," therefore, "where

settlements will be slow, if practicable at all," does the State propose to undertake intensive protection; protection in these cases to be based on private cooperation, "volutary if possible, but compulsory if necessary, in order that these lands may be brought back to a productive condition."

"To permit fire in the woods, either before or after cutting," it is stated, "effectively defeats the purpose of forest replacement." For this reason the burning of slashings is condemned and intensive patrol of slash areas supplemented by special protective measures "along roads, trails, and other places of extreme risk," is advocated. Until public sentiment is aroused, however, it is pointed out that bad and numerous fires will continue to occur, since effective fire protection depends on public support. The conclusion is that, "no fires in the woods" is the solution of Wisconsin's forestry problem.

On the whole the situation in Wisconsin is fairly well presented, although the agricultural possibilities of northern Wisconsin are somewhat optimistically viewed. The program advanced for State effort, however, is decidedly conservative and fails to grasp either the possibilities or necessities of the case, or to recognize the State's responsibility for protecting the interests of future generations. The decided stand taken as to the necessity for absolute fire protection consistently and continuously applied, however, is encouraging.

J. A. M.

Trees of Indiana. By Charles C. Deam. First revised edition. Department of Conservation of Indiana, Publ. 13, 1921.

Deam's "Trees of Indiana" has been entirely rewritten. The value of the first edition was such that 10,000 copies were exhausted in about three years. An additional 1,000 copies printed in 1919 were gone within five days. This is an encouraging sign of the interest in trees and forestry in the State of Indiana, and a tribute to the excellence of the book itself. The book is written for the layman, unfamiliar with botanical terms; but the simplicity of the descriptions has not been secured at the expense of accuracy, and, while enlarging the audience, has not diminished the value of the work to the scientist. If botanical descriptions can be made intelligible without a glossary why cannot the same be done with scientific articles?

For each tree the general distribution is given, followed by the distribution in Indiana. Under the latter there is a considerable amount of valuable material on the soil and moisture requirements, particularly of the more important trees. The uses of each tree in forestry and horticulture are given. The latter, as would be expected, receives a great deal of prominence. There are 134 excellent full-page illustrations, mostly photographs, of leaves and fruit, some also containing the flowers. A map of Indiana showing the "areas of forest distribution" or practically the forest regions, serves not only to show where each species is found, but something of the general nature of its habitat. The author separates out from the main body of the State, and briefly describes the following: the "lake region," about the northern third of the State; the "prarie area," along part of the western margin; the "knob area," the hilliest part of the State, of sandstone formation and occurring in the south; "the flats," a level stretch of compact clay, east of the preceding; and the "lower Wabash valley." The care and thoroughness exercised in preparing the book is indicated by the fact that since the first edition was published, the author has traveled over 27,000 miles in the State (not on trains) and visited every county and almost every township. The book is well printed, with an unusually simple key and good index, making not only a useful but an attractive volume. B. M.

The Pine Resin and Turpentine Industry in India. By A. J. Frazier, I. F. S. Journal of the Oxford University Forest Society, Michaelmas Term, 1921.

The Indian Forest Service first realized the naval stores possibilities of the great pine belt along the lower slopes of the Himalayas about 25 years ago, and since that time has interested itself in the development of this valuable resource. The only species, *Pinus longifolia,* that so far has been dealt with covers about one million acres. Other species suitable for the production of naval stores in India are: *Pinus excelsa, P. khaysa, P. mergusii,* and *P. gerardeana.* These species have yet to be exploited. So far in India only about 100,000 acres are being worked for turpentine, yielding annually 2,500 tons of rosin and 156,000 gallons of turpentine. The consumption of naval stores in India averages 3,300 tons of rosin and 246,000 gallons of turpentine, including substitutes.

In its management for naval stores, the turpentine timber is grouped into depots, sub-blocks and blocks, the unit of working being a section of 1,000 faces (usually covering 25 or 30 acres), allotted to one chipper. The unit of control is a depot taking the output of about 25,000 faces. In common American practice the unit of work is a "crop" of from 8,000 to 10,000 faces allotted to one chipper and the unit of control is an "orchard" or "farm" working from 50,000 to 100,000 faces. The plant used in India for the distillation of the resin is of the French type, using steam heat and steam injection. In the early days of the development the American form of still which uses direct heat was used, but this rather crude system has long since been abandoned. The rosin produced has been favorably reported on by paint and varnish firms. It is graded according to American standards into pale, medium and dark shades. The spirits of turpentine seems to require more treatment than does ours. According to the article, the turpentine is twice distilled and twice pased over trays of lime to remove acidity. In America ordinary commercial spirits of turpentine are the result of one distillation only and no lime bath is required.

The ultimate annual yield from the naval stores region in India may reach 20,000 tons of rosin and over 1,500,000 gallons of turpentine, producing at a conservative valuation an annual income of around $6,000,000, an amount sufficient, according to the author, to pay for the whole Indian Forest Department staff twice over.

The possible annual production of naval stores in India seems small, indeed, when compared with the average production in the United States, namely, 500,000 tons of rosin and 30,000,000 gallons of turpentine, valued at from $30,000,000 to $50,000,000 annually. It is of great interest to Indian foresters in this connection, as it is to us, that the duration of the American source of supply is doomed to early extinction. The article quotes from the Capper Report the estimate of the remaining period that the present production can be maintained, as follows: Alabama, 5 years; Georgia, 6 years; Florida, 8 years; Mississippi, 8 years; Texas, 10 years; Louisiana, 15 years.

The naval stores belt of India is and always has been under the administration of the Indian Forest Service, and is being developed and exploited, fortunately for the industry, under the French system of working and management, which differs from the American practice mainly in that it allows of a continuous sustained yield over a

period of from thirty to fifty years on each stand of timber without serious effect upon the final value of the saw-timber. The American system of working exhausts the naval stores productivity of a stand of timber in from three to five years and leaves it more or less damaged for saw-timber.

Under the wise, far-seeing management of foresters, the naval stores industry of India may with certainty look forward to such a development as that now enjoyed by the naval stores of France. The supply will be continuous, uniform and permanent, with a constantly increasing value for the finished output. How different is the situation in America! The American naval stores belt is all privately owned and is not subject to technical control from any source. Consequently, there is no system of management, little or no advance in refinement of operation, and reforestation, when it occurs at all, is purely accidental. As a consequence, that great American industry, which for the last century has furnished over 80 per cent of the world's supply of naval stores, will soon find itself put away in that dark closet where hangs the body of the famous goose that laid the golden eggs.

I. F. E.

PERIODICAL LITERATURE

SOIL, WATER, AND CLIMATE

Forest Types and Soil

The Durmast or sessile oak (*Quercus sessiflora*) in England occurs commonly on soils derived from the older siliceous rocks. This oak type, Tansley's *Quercetum sessiflorae* is therefore considered calcifuge, confined to acidic rocks. Salisbury and Tansley [1] found an apparent exception in a Durmast forest growing over Wenlock limestone which contains from 60 to 74 per cent of calcium carbonate. The associated plants were also those characteristic of acid soils. Analyses showed that the soil at 3 feet depth contained 7 to 23 per cent of lime, while the surface soil of the forest floor, even after the removal of the litter and raw humus, contained *less than 1 per cent*. Thus the surface "is what would be commonly regarded as a non-calcareous soil." "Not only has leaching resulted in removal of bases but an actual acidity has developed as shown by the high 'lime requirement' of the surface soil . . ."

"The presence of *Q. sessiflora* and its associates on soil derived from calcareous rocks is thus not inconsistent with the predilection of this tree for acid soils . . . ." This interesting study emphasizes the necessity of making actual soil analyses before drawing conclusions as to the relation between forest types or other vegetation, and the underlying geological formation. The authors do not say that, on the other hand, soils derived from siliceous rocks could generally be classed as acid with reasonable assurance.

In field studies, when it is impracticable to make complete analyses, it will be easy to determine whether a soil is basic or acid by use of the Wherry indicators.[2] These furthermore measure with sufficient accuracy for most ordinary purposes the degree of alkalinity or acidity.

B. M.

[1] Salisbury, E. J., and Tansley, A. G. *The Durmast Oak-woods (Querceta sessifloræ) of the Silurian and Malvernian Strata near Malvern.* Jour. of Ecology, Vol. 9, No. 1, pp. 19-38, 1921.

[2] Wherry, E. T. *Soil Acidity and a Field Method for Its Measurement.* Ecology, Vol. 1, No. 3, pp. 160-173, 1920.

Nitrogen and Vegetation

Olsen [1] has made a study of environmental factors and the occurrence of the common stinging nettle. *Urtica dioica* in the Danish forests. He investigated light, moisture, the chemical composition of the easily soluble mineral constituents of the soil, and nitrification, as well as the influence of brush piles in favoring the nettle. The field determinations were supplemented by cultures of the nettle grown in sand to which nitrogen, in some pots as nitrate, and in others as ammonium, had been added.

The conclusion is that the nettle "requires a relatively high amount of nitrogen, which must be supplied in the form of nitrate, whilst ammonium appears to act as a poison on the plant."

The significance of the work, taken in connection with that of Hesselman [2] lies in the increasing body of data on the importance of nitrogen as a factor in the distribution of natural vegetation. The practical silvical bearing of this factor is such that a field method for its determination, analagous to Wherry's indicators [3] for testing acidity and alkalinity, would be of the greatest value.

B. M.

[1] Olsen, Carsten. *The Ecology of Urtica Dioica.* Jour. of Ecology, Vol. 9, No. 1, pp. 1-18, 1921.

[2] Hesselman, H. (Several titles.) Reviews in Jour. of Ecology, Vol. 7, Nos. 3 and 4, pp. 212-213, 1919. JOURNAL OF FORESTRY, Vol. 16, No. 8, pp. 937-938, 1918, and Vol. 17, No. 1, pp. 69-73, 1919. Botanical Abstracts, Vol. 3, entries 564 and 2028, 1920, and Vol. 4, entry 189, 1920. Botanical Gazette, 66: 77, 1918.

[3] Wherry, E. T. *Soil Acidity and a Field Method for its Measurement.* Ecology, Vol. 1, No. 3, pp. 160-173, 1920.

Influence of Peat on Transpiration

The author investigated the cause of the well-known drought resistant or xerophytic characters of bog plants. Both xerophytic and mesophytic plants were grown in peat and in a loam soil in sealed pots.

It was found that "whenever a plant is able to produce a healthy root system it is able to obtain sufficient water from the peat soil to maintain a higher rate of transpiration than that maintained by the same species of plant growing under identical conditions in loam soil." This holds for moist soils and soils dried to a point near the wilting coefficient. The peat had a stunting effect on the roots of *Salix pentandra,* but *Salix cinerea,* as well as birch and sycamore maple.

Acer pseudo-platanus, produced equally healthy roots in both soils. *Epilobium hirsutum* and wheat roots did not grow in the peat. The author concludes that the "xerophylous" structure as a means of checking water loss by transpiration does not seem to be an essential adaptation of bog plants. A conclusion so much at variance with the commonly accepted views concerning bog plants will be received with caution, and will require further study. B. M.

Thatcher, Kathleen M. *The Effect of Peat on the Transpiration and Growth of Certain Plants.* Jour. of Ecology, Vol. 9, No. 1, pp. 39-59, 1921.

SILVICULTURE, PROTECTION, AND EXTENSION

A New Method of Cutting

A new modification of the shelterwood system has been developed by Eberhard in the Black Forest in Wurtemberg. He criticises Wagner's statement that in the shelterwood method the difficulty lies in properly developing the young growth rather than in initial establishment. Eberhard maintains that initial establishment of seedlings is the big problem, and that later development is a relatively simple matter. The primary dangers to avoid are windfall and snow breakage, weed growth, disease and insect infestations. Cuttings and thinnings must be regulated with respect to the adverse factors one has to deal with on the site concerned.

Eberhard's method which deals mainly with silver fir utilizes primarily two types of operations; namely, thinning and soil preparation. Silver fir should be thinned often and lightly. Large openings encourage weeds and windfall. The interval between thinnings varies from one to three years. Frequent thinnings are especially important in the reproduction stage. Reproduction is introduced 20 to 25 years before the end of the rotation. First, the litter is removed, then the mineral soil is exposed in strips. At intervals of 1 to 1½ meters in these strips, squares of one-half meter are hoed to a depth of 40 cm. In many localities, the soil preparation involves no expense because the labor is performed by local inhabitants in return for the litter which they use for bedding. Silver fir, beech and spruce seedlings appear in the thinned stands. The term "light cutting" must not be applied to the cuttings which bring about reproduction because this term implies a strong inroad upon the crown cover at one time. Light must be introduced gradually in order to permit the trees to

adapt themselves and in order to hold the weeds in check. Weeds can be controlled in this way because they endure less shade than the forest seedlings of the species here involved. Reproduction develops with the gradual introduction of light by thinnings or light cutting until it is securely established. Windfall and weeds are now no longer to be feared. All the cuttings up to this point are classed as "*preparatory*;" beyond this stage, they are designated "*after cuttings*." As in the case of "*preparatory cuttings*," "*after cuttings*" occur frequently, preferably every year, until the stand has been converted into a young forest.

The direction in which the regeneration proceeds over a unit depends upon three considerations; namely, prevailing wind direction, aspect of the site, and the direction in which the material is to be hauled. On account of danger from windfall, cutting usually proceeds from east to west; but on slopes this may be varied. Logs must not be skidded or hauled through the stand which has been restocked. In order to avoid suddenly opening up large spaces, the cutting areas take the form of a wedge the point of which is directed toward the west, hence the name "Schirmkeilschlagbetrieb." Wedges are started at intervals of from 80 to 120 meters. The rate of cutting and regeneration can be regulated by increasing or decreasing the number and interval between wedges. At first, the wedges are very narrow and long, but as the cutting progresses they are widened out until finally adjoining wedges coalesce. In the earlier cuttings light is introduced by removal of codominant trees; dominants are left if healthy because they are more windfirm and create a better windbreak than codominants. The borders of the wedge are more or less irregular, so that its shape is often not apparent. Nevertheless, there is always the effect of a gradually increasing crown cover from the middle to the outer edges and from the base to the apex of the wedge. The method is especially adapted to silver fir because seedlings of this species may remain suppressed for 25 years, and when released spring up as if they were only 3 or 4 years old. Oftentimes the seedlings start in the virgin stand before cutting is begun, but they develop only as cutting proceeds. Eberhard claims the following advantages for his method over that of Wagner, evidently referring to Wagner's border cutting:

1. It shortens the hauling or skidding distance to the roads by about one-half.

2. It gives better natural reproduction and better protection against wind.

3. A unit can be covered more rapidly, thus giving larger annual cuts and shortening the reproduction period.

4. It maintains the original uniformity of the stand and does not necessitate a rearrangement of age-classes as in the Wagner method.

The writer believes that Eberhard's method offers many valuable suggestions for southern Sweden, but does not consider it at all applicable to northern Sweden where conditions are entirely different from those of the Black Forest. G. A. P.

Petrini, Sven. *Ett modernt Avverknings-system—Schirmkeilschlag contra Wagner Blädning.* Skogsvårdsföreningens Tidskr. 19: 115-128, fig. 1-2, 1921.

Delayed Germination in Scotch Pine

Swedish foresters have experienced considerable variation in the rapidity of germination of pine seed (*Pinus silvestris*) from different localities. Seed from Norrland, the northmost forest region of Sweden, germinates slowly both in its native habitat and in the warmer localities of southern Sweden.

Oldertz proceeds upon the theory that deferred germination may be due to subnormal development of the embryo. Extremely short growing seasons such as prevail in Norrland might bring about such a condition. In seed from southern Sweden the ratio of length of embryo to length of endosperm was found to be 97.6 per cent maximum and 62.7 per cent minimum. In the best samples of Norrland seed, the maximum was 93.9 per cent and the minimum 19.2 per cent. Some seeds were found to contain two or three embryos of which only one was developed. Further tests show that seeds with large embryo give the highest germination within a period of thirty days. The percentage of seeds having an embryo of endosperm ratio of over 75 per cent agrees closely with the percentage of germination in thirty days. It is further demonstrated that the embryos of seeds which remain ungerminated at the end of thirty days have undergone a marked growth, and that they will germinate in time unless attacked by mould or other diseases. It is concluded from these experiments that the reason why a large per cent of Norrland seed lies over is that the embryo had not attained sufficient development when growth on the tree was brought to a close by low temperature.

As is well known, pine cones require two years to mature. The pollen grain germinates and sends its tube down into the pistil during the first season, but fertilization does not take place until the second season. After fertilization the embryo develops and the seed grows toward maturity. It is evident that a material shortening of the vegetative period might arrest the development of the embryo. According to investigations in Norway, Scotch pine requires a mean temperature of not less than 10.5° C. in June, July and August in order to produce viable seed. In upper Norrland the average margin above this minimum is only about 1.5° C. The temperature of the second growing season is considered more important than that of the first.

G. A. P.

Oldertz, Carl. *Orsaker till Eftergroning hos Norrland Tallens Fro.* Skogsvårdsforeningens Tidskr. 19: 157-172, fig. 1-5, 1921.

Regeneration of Sal Forests

The ecological character of sal regeneration has been studied since 1909 and a long series of experiments have been carried on. Seed of the sal has been found to be very liable to injury through drouth or through long immersion in water, and by using great care, the seed may be kept a month in storage.

In propagating the sal, buried seeds do better than those merely scattered on the surface of the ground. On broadcasting the seed, at least six seeds to the square foot are necessary to secure a stand. Shade is inimical to the young plant, when too heavy, but some shade in the late afternoon is desirable to avoid the effect of the hot sun. The radicle is often prevented from reaching the soil by a surface covering of the large dead leaves which cause the radicle to shrivel up because of a lack of moisture. Heavier layers of this litter appear to cause a condition ascribed to bad soil aeration. Burning the surface litter help to improve the germination and while it does not reduce the number of seedlings it seems to reduce height growth.

Soil composition as such has little effect upon the growth of sal seedlings, but in its relationship to the moisture condition is very important as soil moisture is a limiting factor. In the work as carried out, it was found that when the water content fell below three per cent in sand or sandy loam, or below ten per cent in loam, the seedlings died back, while during the very dry season, the sprouts die back even when several years old when the soil moisture is depleted.

Poor soil aeration, the result of either compacted soil or standing water, is another limiting factor with the sal. In such cases, root growth is slight and that of the aerial parts is slow. This can be quickly remedied by the removal of the surface litter or the loosening of the soil.

In field practice, the best regeneration is obtained from clearings, the width of the clearing being the height of the adjacent stand, the clearing proceeding from east to west to give afternoon shade. Narrow clearings are necessary to avoid frost damage and the growth of weeds. Under partial shade, weeds are kept down but at the expense of growth. Some weeding appears necessary to reduce the drain on the soil moisture and to keep down a rank growth which would choke the trees at first.

Height growth of the trees varies greatly according to conditions under which grown. Under irrigation and without competition, a growth of 32 inches a year has been secured. Elsewhere the growth is from 8.6 to 11.5 inches per annum. E. N. M.

Hole, R. S. *The Regeneration of Sal (Shorea robusta)* Forests. Indian Forest Records, 8: Part II, 163-227, 8 pl. 1921.

Commercial Concentration of Regeneration Fellings

A study of costs has led the Indian Forest Service to consider methods for the concentration of regeneration fellings in the Himalayas in order to reduce the cost of logging. With the help of an American logging expert, a scheme has recently been drawn up for logging in the Bashahr division in the Himalaya Mountains. They are to construct roads, slides, a flume, splash dams, and a modern saw-mill is to be erected on the Setluj River, 12 miles from the forest areas. This modern method of logging is to replace the old-fashioned method of hand-sawing ties in the forest with transport on cooly back to the river, which it is estimated resulted in a loss of about 16 cents per tie.

Discussing the same subject, C. S. Martin, Consulting Forest Engineer to the Government of India, cites methods to obtain the fullest utilization and the greatest revenue from these forest resources: Departmental exploitation and organization of a separate staff. The financial success of such a scheme will depend on building up an efficient staff and the usual difficulty of Government purchases of machinery and supplies,

difficulty of securing high labor efficiency and the decentralization of authority. Three ways out of the difficulty are suggested: (*a*) For the Government to form a limited partnership with reliable private firms; (*b*) to organize Government finance companies, all profits or losses to be retained by the Government, or (*c*) to have an "Indian" forest engineer and exploitation service to work as an integral part of the forest department. (*a*) and (*b*) are thought to be impracticable and contrary to good politics, so Martin believes that method (*c*) would give the best results and predicts *double to ten times the present revenue* and improvement of silvical conditions in the forests, but he realizes that the training of the men and the creation of a proper organization will take time. T. S. W., Jr.

Jerram, M. R. K. *The Commercial Concentration of Regeneration Operations in the Punjab Himilayas.* Indian Forester, 47: 229-233, 1921.

Martin, C. S. *General Note on Future of Departmental Exploitation in the Punjab.* Indian Forester, 47: 399-406, 1921.

Development of Forest Management

Trevor sounds a note of warning about adopting any preconceived notion of silvicultural practice for forests in British India without taking into consideration "the true principles of the silviculture of trees with which we are dealing in its special environment, and (by) the requirements of the local conditions . . . ." He quotes at length from Hawley's "Practice of Silviculture" in describing the selection system. Trevor says that "good management consists in a compromise of all the factors of silviculture, exploitation, staff and labor, rights and local requirements existing in the area at the time of the compilation of the working plan." He argues against the adoption of American logging where "it has been calmly proposed to clear fell and plant whole valleys of spruce and silver fir when it is well known that a shelterwood is almost imperative for the latter species." T. S. W., Jr.

Trevor, C. G. *Forest Management.* Indian Forester, 12: 491-502.

The June Beetle

The June beetle (*Melolontha vulgaris* F.) has been fought for two centuries by agriculturists, foresters, and nurserymen without appreciable result. It is one of the most polyphagous of insects and does much

damage both in the larval and the perfect form. Birds and mammals destroy comparatively small numbers, and inoculation with fungi and bacilli has not proved particularly effective. Treatment of the soil with 40-50 grams of carbon bisulfide per square meter has materially reduced the loss in nurseries and has at the same time stimulated seedling growth. Compact clayey soils suffer comparatively little. Real progress in controlling the pest cannot be hoped for until the governments concerned make compulsory a concerted and energetic fight throughout the affected regions. Present measures are merely palliatives.

S. T. D.

Barbey, A. *Le hanneton.* [Review of: Decoppet. *Le hanneton.* Lausanne, librairie Payot et Cie., 1920.] Rev. Eaux et Forêts, 59:73-76, 1921.

Principal Species of Exotics

Since 1900 accurate records have been kept on a considerable number of exotic tree species, largely American, planted at Barres. The results secured with the more important of these, including thirty-one hardwoods and forty-one conifers, are presented herewith. They show that, while certain foreign species on which exaggerated hopes had been built are absolutely without future in France, at least under the conditions existing at Barres, others because of their beauty and remarkably rapid growth are of very great interest. Prominent among the latter are incense cedar, bigtree, redwood, Calabrian pine, Corsican pine, Atlas cedar, Nordmann fir, and, especially, Douglas fir, alpine fir, and grand fir. The results of the experiments, in spite of the indifference to exotics manifested by most foresters, have proved that they are of great importance and unquestionably worth continuing. S. T. D.

Parde, L. *Les principales essences exotiques dons l'arboretum national des Barres de 1900 a 1920.* Rev. Eaux et Forêts, 59:134-138, 166-173, 1921.

Reaction Against Clear Cutting

The reaction against clear cutting of pine stands in Germany started by an article by the Oberforstmeister, Dr. Alfred Möller, in the January, 1920, number of Zeitschrift fur Forst- und Jagdwessen, has caused a reconsideration of clear cutting in Belgium, which the Germans practiced to excess during the war, and which

private owners have been practicing since the war because of the high prices which have prevailed. The new slogan is "No clear cutting, instead—the continual forest." This policy has for a long time been dominant in France, nor is it new in Holland. Those who are interested in the development of this German policy had best refer to the original article by Möller. An important phase of the new policy is the leaving of the leaf and branch litter on the soil, notwithstanding the slightly increased danger from fire. T. S. W., Jr.

Drumaux, L. Bulletin de la S. C. F. de Belgique, 29: 1-24, 1921.

Deforestation of the Ballon of Alsace

The upper basin of the Savoreuse River, reaching a maximum elevation of 1,242 meters on the Ballon of Alsace contains 1,250 hectares, of which 1,150 hectares are covered with a mixed high forest of broadleafs and conifers. From 1916 to 1919 unusually heavy and intensive cuttings in these stands led to the deforestation of some 300 hectares and seriously disturbed normal forest conditions over large additional areas. These changes resulted during the winter of 1919-1920 in unprecedentedly severe floods in the Savoreuse River, the total direct damages from which amounted to 164,000 francs as against a maximum of 4,500 francs in any previous year. At the request of the local residents the State is now taking steps to establish zones in which reforestation is obligatory, under the laws of April 4, 1882, and August 16, 1913, and also to purchase some 580 hectares in the two principal forests. S. T. D.

Bourquet. *Les déboisements du Ballon d'Alsace.* Bull. Trimest. Soc. Forest. Franche-Comté et Belfort, 13:225-237, 1920.

French Forest Commission

On August 19, 1921, a special anti-forest fire commission was established in France under the presidency of Antoni, Inspector General of Waters and Forests. This commission has been established on account of the large fire losses due to the drought in 1921 and due to fires that took place in the South of France during the war. T. S. W., Jr.

Review des Eaux et Forêts, 49: 355-356, 1921.

MENSURATION, FINANCE, AND MANAGEMENT

Future Value

In calculating the future value, as a basis for reparations, of trees destroyed by the Germans, it is helpful to make use of Pressler's famous trinomial ($a + b + c$), in which a represents the per cent of current volume growth of the tree, b the per cent of increase in quality resulting from increase in size, and c the per cent of increase in value resulting from rising prices of wood. Trees over 40 cm. in diameter usually have no future value because for larger trees b is negative, making the sum of $a + b$ less than c. The great and definitely known increase in price during the last seven years, however, gives a positive future value to trees up to 60 cm. in diameter. In the case of young oak standards for this period c amounts to 15 per cent, to which may be added 2 per cent for current annual volume growth (a), making a total of 17 per cent even if b is ignored entirely. S. T. D.

A. S. *Valeur d'avenir.* Rev. Eaux et Forêts, 59:71-72, 1921.

Yield Regulation Methods in British India

Robbins reviews the French system of "successive regeneration, fellings, and thinnings" by periods and periodic blocks introduced into France in 1820 and explains how the so-called Duchaufour's method is applied by the formula, "$P = \frac{V \times S}{C \times R}$, where V = total value of groups I and II plus 2 per cent increment; S = total wooded area of the series; C = real area of the compartments of group II together with the reduced area of the compartments of group I; R = reduction, e. g., 150 acres." In commenting upon the application of this formula, Robbins states:

"The only unknown quantity here is C, the combined area of groups I and II and the ascertainment of its value is based on the theory that in regular high forest each stem can develop normally, only when it occupies a space proportional to the square of the diameter of the trunk. This space can be measured as a square constructed on a side equal to K times the diameter. K is the co-efficient of density. The area of a compartment of even-aged high forest containing 'n' trees of a mean diameter (D) is $(KD)^2n = K^2D^2n$. From numerous measurements of fully stocked crops of group II it has been found that K has an

average value of 16 and this holds true for all the series. Therefore $C = 16^2D^2n$.

This has been verified in several fully-stocked crops in the forest and the actual area has been found to be equal to the theoretical area calculated with this co-efficient. As an example compartment 21 in the I felling series has an actual area of 25 hectares. Number of trees = 5,253. Volume of these trees = 7,165 cubic meters. Average volume per tree = 1.364 cubic meters.

Volume tables show that the nearest diameter corresponding to this volume is 0.45 meters, which gives a volume of 1.500 cubic meters. The required average diameter is therefore given by $\frac{D^2}{d^2} = \frac{1.364}{1.500}$ where $d = 0.45$ (where $D^2 = 0.184$).

The reduced area of the compartment is therefore

$$= K^2D^2n.$$
$$= 16^2 \times 0.184 \times 5{,}253.$$
$$= 24.74 \text{ hectares.}$$

This is very nearly equal to 25 hectares, the real area. The necessary substitution for C gives possibility $= \frac{V \times S}{R \times K^2D^2n}$ where K is 16."

T. S. W., Jr.

Robbins, C. R. *The Swing of the Pendulum—A Description of Duchaufour's Method.* Indian Forester, 47: 443-452, 1921.

Increasing the Production of Timber

The General Councils of the Departments of the Haute Saône and the Jura have expressed their desire to support the efforts of the Forest Service; to secure the submission to the forest régime and the reforestation of waste areas belonging to the communes; to increase the proportion of conifers in the mountains; and to convert the stands of broadleaf coppice in the plains into high forest by increasing the number of young reserves. The conservators of waters and forests in these two departments have expressed their approval of this program to increase the production of timber, and have issued instructions accordingly to the forest force.

S. T. D.

Anonymous. *Voeux votés par les conseils généraux de la Haute-Saône et du Jura tendant à l'augmentation de la production du bois d'oeuvre.* Bull. Trimest. Soc. Forest. Franche-Comté et Belfort, 13:283-288, 1920.

Interest in Forest Investments

Indian foresters in their valuation calculations are having difficulty in deciding on a proper rate of interest. Quoting from Chapman's "Valuation," sections 52 and 53, Blanford advocates a fixed rate of about 4 per cent, notwithstanding the present fluctuations in the cost of money.

T. S. W., Jr.

Blanford, H. R. *Rate of Interest in Forest Investments.* Indian Forester, 47: 283-285, 1921.

UTILIZATION, MARKET, AND TECHNOLOGY

Increased Values in Belgium

According to Pechon, the Belgium Government has often been criticized for making bad forest bargains when purchasing new forests. He now cites a notable exception in the case of the forest of Le Beynert, about 400 acres in area, purchased by the State in December, 1904, for 225,000 francs or, at the prevailing rate of exchange, $43,425. In 1921 the appraised value of the forest had risen to 621.200 francs, an increase of almost 300 per cent. It should be noted, however, that today the forest is worth only $50,317.20 at the prevailing rate of exchange, whereas if present values continue and the rate of exchange becomes normal, the value would be $119,891.60. From the figures presented by Pechon it is interesting to note that the land value is figured at about $58 per hectare (normal exchange) and that the growing stock of broadleaf timber is valued at about $800 a hectare. Moreover, the revenue since 1904 has been only 25,000 francs, so that it is clear that a much abused forest is being whipped into proper shape by economy.

T. S. W., Jr.

Pechon, L. Bulletin de la S. C. F. de Belgique, 29: 24-27, 1921.

STATISTICS AND HISTORY

The Coniferous Forest Resources of the World

This article, being presented to Swedish readers, treats the subject from a Swedish viewpoint. Sweden, unlike most European countries, is interested in the world's timber supply, not as a buyer but as a seller. Forest products are Sweden's foremost commodity of export. Nearly one-half the land area is forested. Large areas of virgin timber still remain, and the prac-

tice of forestry is in an advanced stage. Although the timber resources of such a small country are a minor factor in the world's market they are of tremendous importance to Sweden. Conifers alone are treated in this article because of their overwhelming preponderance in the timber markets, and because practically all of Sweden's export wood falls in this class.

The southern hemisphere is credited with a relatively small amount of coniferous forest. The only bodies of any consequence are the so-called Paraná pine in southern Brazil and northern Argentine, and the Kauri pine in New Zealand, neither of which are true pines. Paraná pine (*Araucaria braziliana*) is a stately tree and forms the most extensive coniferous forests in the southern hemisphere. The wood is loose-fibered and generally inferior to that of the true pines. A serious defect is that the knots are inclined to fall out when dry. During the war, when importations were cut off, the lumber industry in Brazil made rapid strides. Brazil now not only supplies her own needs but exports considerable quantities of Paraná pine to other South American countries. Kauri pine (*Agathis australis*) in New Zealand is rated as one of the finest conifers in the world. The forests are, however, practically exhausted. Other countries south of the Equator have very limited supplies of coniferous timber or of hardwoods which can take its place. During the past decade, conifers from the northern hemisphere have been planted to a considerable extent, and it is predicted that in time these plantations will attain great importance. For at least fifty years, however, the southern hemisphere will continue to be dependent for its soft woods largely upon importations from the north.

Turning to the northern hemisphere, it is pointed out that most of the present timber supplies represent the growth of the past 200 to 300 years. Notwithstanding the possibilities of increased production, timber prices are bound to be higher in the future than in the past, because future supplies grown under management must carry the cost of production, whereas in the case of virgin stands there was no such cost. Most countries experience a shortage between the exhaustion of virgin supplies and the time when second growth attains merchantable size. Many of the largest timber regions are now in that stage. Sweden is more fortunate than most nations in that she began the practice of forestry in time to avert a timber shortage.

The United States and Canada are treated as one unit. To American foresters who are already familiar with conditions in this country the discussion is of interest mainly as presenting the viewpoint to an outsider. The to us well known facts regarding the depletion of one large timber region after another, the devastation by private operators, the appalling loss by fires and the great discrepany between rate of consumption and rate of growth, are vividly recounted. The writer refers humorously but significantly to the adornment of the streets in our eastern cities with telephone poles shipped from the Pacific Coast. He gives due credit to the recent developments in our fire protection systems, in certain regions, but is at a loss to understand our public disregard for fires. The southern pine belt is regarded as a counterpart to the similar forests which once occupied the Mediterranean region, but of which now only a few remnants remain. Our southern pine forests are credited with an area more than twice as great as the entire land surface of Sweden. The extreme north Pacific Coast belt is ranked as the world's greatest source of accessible pulpwood. It is predicted that British Columbia will in the not far distant future be the center of the greatest pulp industry in the world. Forestry is considered to be making remarkable advances in the United States, but was started too late to make the most of the wonderful possibilities here existing. American foresters are given a high rank in their profession as regards training and progress in research.

Japan has a variety of conifers, some of which yield excellent material; but notwithstanding that the forests occupy a considerable percentage of the country's area and that they are being carefully managed, Japan will continue to import large quantities of both lumber and pulp. Whether Japan and China will be able to supply their needs from the mainland of eastern Asia and the Island of Saghalien seems to be more or less of an unanswered question. A considerable pulp industry has developed in Saghalien in recent years. In 1915 the output was 4,676 tons, which in 1918 had risen to 143,500 tons.

The coniferous forests of eastern Asia are now limited to the Manchuria and Amur where large quantities of timber occur. Vladivostok was making extensive harbor improvements for handling timber when the war broke out. Colonization in Amur during the past decade has brought in considerable amounts of labor. All available

information indicates that the forests in these regions have suffered severely from fire and that reproduction comes in slowly. On the whole, Siberia's timber resources are thought to have been generally overrated. It is true that tremendous areas are covered by forest, but the stands are open and the trees are often small and slow growing. Interior transportation problems are considered the greatest obstacle in exporting Siberian timber.

South and west China contain limited amounts of coniferous timber, mainly difficult of access.

Extensive forests are found in the Hymalayas. Above an elevation of 1,000 meters the tropical vegetation gives way to broad-leaved forests and the long-needled pine (*Pinus longifolia*) which occurs in considerable quantity. The true coniferous belt lies between altitudes of 1,800 and 3,800 meters. This belt contains one of the world's greatest reserves of coniferous timber, rich in both variety and quality. Hymalaya cedar (*Cedrus deodara*) is the principal saw timber tree. *Pinus excelsas,* a near relative of the American *Pinus strobus* is also highly esteemed. The spruce of this region is *Picea morinda.* A very large and beautiful fir (*Abies webbiana*) occurs extensively throughout the regions at altitudes of from 1,800 to 4,000 meters. The spruce and the fir are capable of furnishing abundant supplies of pulp material. Forestry under British rule has received careful attention. The greatest problem is transportation. India with its teeming millions should furnish a good market, but on account of the shortage of fuel, it has been found difficult to operate railroads in the mountains. Water transportation is unsatisfactory because of steep gradients and a great fluctuation in the flow of mountain streams. The result of these circumstances is that India has heretofore been a timber importing country. The writer thinks that the country will be doing well if eventually it becomes self-sustaining, excepting that it may be able to export pulp material.

In Europe the two remaining large forest regions are (1) northern Russia and Scandinavia, and (2) southern Europe from the Pyrenees and Switzerland through the Alps, the Bohemian Mountains, the Carpathians and Balkans.

In the last named region from 25 to 50 per cent of the various political divisions are forested. In the higher altitudes coniferous forests predominate, including spruce (*Picea excelsa*), fir (*Abies pectinata*) with more or less beech in mixture. In the higher portions of the

Alps are extensive stands of European larch (*Larix europea*). Pine (*Pinus silvestris* and *Pinus austriaca*) occurs sparingly. Prior to the world war, Austro-Hungary and Roumania had developed their lines of transportation with reference to the marketing of their great timber resources, with the result that Austro-Hungary became the foremost timber exporting nation in Europe, although she was later exceeded by Russia. The Mediterranean countries, Germany and, to some extent, southern Russia, were before the war the markets for this forest region. Spruce grows much more rapidly here than in Sweden, but reproduction is often difficult in that beech tends to replace spruce after cutting. The present political upheaval will adversely affect the timber export business for some time, particularly because of the interruption of transportation, but it is anticipated that foreign capital will eventually restore the industry.

Northern Russia is typically a forest region and southern Russia is a steppe region. The northern forest region covers about 147 million acres of forest bearing land and comprises three-fourths of the old European Russia's forest area. Pine (*Pinus silvestris*), Siberian fir (*Abies siberica*), Siberian larch (*Larix siberica*) and Cembran pine (*Pinus cembra*) are the most prominent species. A great difficulty in utilizing these tremendous virgin stands lies in the transportation problem. The land is extremely flat, and consequently the streams have but a slight fall. There is a great variation between high and low water level. Streams which flow into the Arctic Ocean thaw out first at their sources which lie to the south, with the result that they overflow their banks. Nevertheless water transportation furnishes the only feasible outlet at the present time. Only when prices have advanced materially will the bulk of Russia's timber become available. Large areas have been destroyed by fire during the recent revolutionary period.

It is the writer's opinion that the forests of England, France, and Germany, although damaged during the war, will, owing to decreased purchasing power in these countries, occupy about the same relative importance in the timber market as before the war.

The conclusion of this survey is that the timber resources which under present economic conditions can compete in the world markets are far more limited than is generally supposed. Naturally the outlook is bright from the viewpoint of a nation having large supplies of timber available for export. The article closes with the admonition

that the future of Sweden now demands not only exploitation but production such as can be achieved only by practicing forestry.

G. A. P.

Andersson, Gunnar. *Werldens Barrskogstillgångar.* Skogsvårdsföreningens Tidskr. 19:1-32, fig. 1-8, 1921.

POLITICS, EDUCATION, AND LEGISLATION

Forest Economics in Norrland

Norrland is a large, sparsely settled province in Northern Sweden. Timber is one of its greatest resources. The population has increased steadily since 1870, and this growth has gone hand in hand with the growth of the timber business. Much criticism has been directed against lumbermen because of their acquisition and devastation of timberlands. Although this exploitation is deplored, it is pointed out that the lumber industry is not entirely to blame and that on the whole the economic development of the region was favored. The statement is made that lumber interests control only 20 per cent of the land in Norrland but is not clear that this applies to timberlands. Colonization has been in progress for a number of years. It is pointed out that the presence of industries furnishing employment to settlers is essential to successful settlement. The lumber industry has furnished such employment in the past; a stable forest policy will assure its permanence. Although destructive logging has been the rule in past years, and private owners are still inclined to sacrifice future for present returns, there are many examples of intensive forestry by private owners. National forest laws now prohibit forest devastation on private as well as public lands. Apparently the enforcement of these laws is dependent in a large measure upon the good will of the owner.

In the more remote sections, the practice of forestry encounters difficulties in shortage of labor, lack of housing facilities, and inadequate transportation. The remedy for the first two of these conditions lies in agricultural settlement, and, as has been shown, agricultural settlement is in turn dependent upon the employment and presumably the markets furnished by lumbering and forestry. Emphasis is placed upon the importance of fostering among settlers a favorable sentiment toward forestry, both as a means of creating a source of dependable labor, and as a means of encouraging the practice of forestry by

farmers. Removal of certain legal restrictions which hamper the lumber industry as well as the farmer and laborer is urged. Particular reference is made to a law enacted about 1895 which prohibited the separation of timber from farm land in the sale of farms. The law was designed to stop speculation in timber lands. It now prevents the consolidation of holdings by owners who desire to practice forestry. It also prevents the purchase of farm land by home builders who are financially unable to buy the timber which usually goes with the farms. The article concludes with an appeal for cooperation between the lumber industry, forestry and agriculture as the only solution for the economic problems of Norrland.

G. A. P.

Ekman, Wilh. *Några Skogspolitiska Problem för Norrland.* Skogsvårdsföreningens Tidskr. 19: 33-50 and 77-101, fig. 1-19, 1921.

Timber Exhibits in England

The war proved that timber production is a key industry in Great Britain and resulted in the formulation of plans for the afforestation within the next 80 years of 1,770,000 acres of conifers, of which 250,000 acres are to be planted during the first 10 years. From July 5 to 17, 1920, an empire timber exhibition was held at London in which 18 dominions and colonies participated. The catalog of the exhibit calls attention to the fact that during the period from 1909 to 1913 Great Britain imported 83 per cent of its logs and lumber, 94 per cent of its wood pulp, and 96 per cent of its manufactured wood products; and emphasizes the need for the general public to shake off its apathy regarding forestry matters. Lists are given of the species (461) and products exhibited, of the shippers (264) participating in the exhibition, of British importers, and of publications relating to colonial woods. An interesting collection of articles dealing with wood imports, British ports, forest exploitation by other countries, and various wood-working machinery is also contained in a publication entitled "Timber and Wood-working Machinery," issued by the wood-using industries of England. S. T. D.

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(Compiled by Helen E. Stockbridge, Librarian, U. S. Forest Service)

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EDITORIAL COMMENT

Hard-Headed Regeneration

Save by Sherman, the humor of the situation brought out by Berry's article in the December Journal, "The Value of Young Growth on Cut-over Land," seems to have passed unnoticed. Perhaps that side of the problem deserves brief comment.

Here is a lumberman who has been operating on the area in question for twenty years. Congress has authorized an exchange of his cut-over lands for National Forest stumpage. Consequently, "before making a formal offer of exchange to the Government, the owner desired to have definite information as to the condition and distribution of the young growth in order to make possible the consideration of its amount and quality in arriving at the total value to be put upon the lands offered." In due time forest school graduates are put upon the job of surveying his cut-over lands, and the survey is made in great detail, the young growth being divided into Classes Ia, Ib, II, III, and so on. It appears that about 17 per cent of the lands are classed as well stocked (meaning about three-fourths stocked), that some 52 per cent is classed as partly stocked (meaning a little over one-fourth stocked), and that about 31 per cent is classed as barren, or devastated. The well stocked area is mostly on lands logged in the old days, under primitive methods, while fire added to sky line and high lead logging accounts for the devastated and poorly stocked ground.

This is surely a laudable study; but it strikes us as a bit unusual for a lumberman who has always considered young growth as mere "brush."

Following along, we then read that ". . . the owner is justified in considering that there is a difference in value between non-restocked lands and lands with reproduction."

Well! A lumberman changing "brush" into "reproduction" with a notion that the latter has a real value!

Still, why not? Peavy calls our attention to the fact that we are dealing with a "hard-headed logger in the West" and that his interest in the matter is "indicative of the fact that an appreciation of for-

estry principles, in a small way at least, is entering the minds of those whom foresters have long sought to impress, namely, the practical lumbermen."

Let's see. For the past twenty years this hard-headed lumberman has neglected to keep his cut-over lands adequately productive. For years past he has logged his lands so destructively and protected them so inefficiently that only 17 per cent of them show a decent young growth, while a third of them are devastated. As Berry remarks, he has operated "without thought of a second growth, and with fire protection largely only from the standpoint of protecting logging operations." And now he calls attention to such young growth as has survived his destructive methods, accidental reproduction which has managed to pull through in spite of his utter disregard of its value. This might be termed unwished for increment.

Peavy figures that the lands classed as 1a have a value not to exceed \$18.64 per acre (based on expectation value). We shall not attempt here to discuss the soundness of Peavy's calculations. It is worth while, however, to call attention to the fact that \$18.64 per acre for land three-fourths stocked with 16-year-old trees is a better asset to hang on to, even if not sold immediately, than devastated land with a value, perhaps, of from \$2.50 to \$3 per acre for grazing purposes.

Miller remarks that in Idaho the lumbermen are not letting their cut-over lands go for taxes, but are holding them with the expectation that they can be disposed of at some sort of price later on. Quite so. And this is the case generally throughout the whole country. Lumbermen are holding their cut-over lands. If they had kept these lands productive would they not be somewhat better off today? In part of the East and South cut-over lands fairly stocked with young growth already have a greater market value than devastated cut-over lands, and this market value is reflected in Government purchases under the Weeks law. This state of affairs will soon be apparent in the West.

Incidentally, our practical lumberman has introduced high lead logging on his property and, so far as we know, intends to continue its use. High lead logging, in the pine forests of California, is nothing short of an abomination, for it leaves the logged area wrecked and skinned and sets back the development of a future merchantable stand from 20 to 50 years. So, while endeavoring to impress Uncle Sam with the value of this accidental young growth, he is proceeding

with great efficiency to make sure that he doesn't leave any in the future. This seems a trifle inconsistent.

Now that the policy for State control of forest devastation has been held up to the light and found to be somewhat too transparent for hard-headed usage, it is evident that the Federal Government must sooner or later compel private timberland owners to keep their cut-over lands productive. It seems, therefore, unfortunate that lumbermen have not done this voluntarily for the past twenty years, thus both adding to their land assets and forestalling the necessity for compulsory legislation.

Peavy, in mentioning that the practical lumberman in this instance has begun to appreciate forestry, remarks that " . . . the approach is by the vital avenue of the pocket book, but so much the better. Through no other channel will private forestry ever be established, anyway." We do not believe that Peavy really means to overlook the public welfare side of the matter by basing his hope for the practice of forestry solely on the private owner's pocket-book. He teaches forestry at an institution supported directly by the public and must, therefore, fully comprehend the very vital interest the public has in the practice of forestry on privately owned lands because of the effects of forest devastation on the comfort, prosperity, and safety of the Nation.

F. E. O.

NOTES

Remarkable Pine Growth

Ordinarily the pine is not thought of as remarkable for its rate of growth, yet the results attained by plantations of Pinus insignis here in Victoria, Australia, certainly place this tree as among the most rapid growing species. Not until I had actually seen for myself, however, did I appreciate the significance of data which have been published in regard to the growth of this remarkable tree. I have seen a number of plantations of this pine in Victoria, including those referred to by the writer quoted below, and I can vouch for the reliability of his statements. The growth has simply amazed me. In a brief article in the Australian Forestry Journal (Sydney), July 15, 1921, Mr. Owen Jones, chairman of the Victorian Forests Commission, gives some very interesting data concerning this California Monterey pine growing on the Ovens River gold fields near Bright.

"The areas operated upon are the tailings left after the gold dredges have completed their task, and consist almost entirely of shingle and gravel, soil of any sort existing only in small patches here and there. The planting operations were started in 1916 and have been continued every year since. . . .

"The trees generally present a remarkably healthy appearance, being almost entirely free from disease of any kind, and being well furnished with needles of good color. The height growth for the first three years is in most cases fairly normal amounting on an average to about 3 feet, but once that stage is past many of them are beginning to shoot up in a truly remarkable manner. In the Porepunkah area, planted in 1917, the average height is about 8 feet with individual trees up to 19 feet 2 inches, and presenting a strong healthy appearance throughout. (In another area), measurements taken in May, 1921, disclosed a record growth of 30 feet 3 inches in height (only 3½ years old) with a diameter of 4½ inches at 2 feet from the ground. *The last year's growth of this particular tree reached the astonishing figure of 19 feet 9 inches* with a diameter at its lower portion of 3½ inches! (This is a good record for a single year's growth of a pine tree!) Other trees in this area were measured with diameters of 6 inches and 5¼ at 2 feet from the ground, and with single year's growths of 6 feet 9 inches, 10 feet 1 inch, and 16 feet, the last having a diameter (at the lower end of the year's growth) of 3 inches."

The explanation suggested for this remarkable growth is worthy of general consideration:

"This appears to be found in the operation of the dredges. Although these operations at first sight apparently render the areas quite useless, they do in effect give the ground a very thorough working. The soil and subsoil are broken up and mixed thoroughly together, with the result that the fine root fibres are able to ramify freely, whilst the breaking of the capillary tubes helps to preserve moisture. The original surface, which as might be expected on river flats was of good quality, has filtered down through the interstices between the stones and gravel, so that though the upper layer is at present poor in nutritive substances, there is good material below to which the roots are able to penetrate owing to the loosened condition of the ground. This suggests an explanation of the great increase in height growth after the first 3 years, the trees being by that time firmly established and quite capable of taking full advantage of the good soil to which their roots have now reached."

Mr. H. Mackay, Forest Commissioner, says of this tree, in "Handbook of Victoria," 1914:

"Its transport to Australia affords the only example with which I am acquainted where a tree planted as an exotic, and under the influence of a more equable climate and stronger soil, produces a better and stronger timber than in its natural home."

Some of the plantations of this pine in Victoria are now 40 years old and yield excellent saw timber, except for knots, as it does not lose its early branches readily.

It would be interesting to hear of other examples of remarkable growth of Monterey pine. HARRY D. TIEMANN.

Two New Forest Experiment Stations

During the past summer two new forest experiment stations were established by the Forest Service in the eastern United States—the Appalachian Forest Experiment Station, with headquarters at Asheville, N. C., and the Southern Forest Experiment Station, with headquarters at New Orleans, La. The Southern Appalachian Mountain Region, including the Cumberland, Allegheny, and Piedmont Plateaus, is the center of operations of the Appalachian Station, which will work also in the Coastal Plain Region of North Carolina, Virginia, Maryland and Delaware. The staff assigned to this station includes E. T. Frothingham, E. F. McCarthy, C. F. Korstian and F. W. Haasis.

The Southern Station, with the great Southern Pine Region, from Texas to South Carolina and Florida, as its field of work, is directed by R. D. Forbes, assisted by Lenthall Wyman, F. H. Miller, and W. R. Hine.

The work of the stations has, at the outset, been largely concerned with "minimum requirements" necessary to keep forest lands productive, but other investigations have also been started, notably the study of growth and yield of the southern pines, at the Southern Station, of southern white cedar and of the Biltmore plantations at the Appalachian Station.

A series of forest experiment stations were established in the West from 1908 to 1913 to meet the urgent need for reliable data as a basis for the practice of sound forestry on the National Forests. The demand for similar information in the Southeast for use on the National Forests, and especially on the enormous areas of forest land in private ownership, has only recently developed. The need for forest research and forestry in these two regions is the more urgent because present knowledge of these forests is so limited. These two forest experiment stations in the southern mountains and coastal plains have a splendid opportunity to contribute to the advancement of forestry in the Southeast.

Half Million Dollars Spent to Save the Redwoods in California

According to the Annual Report for 1921, issued by the Save the Redwoods League, half a million dollars have been applied to the saving of redwoods in Humboldt County. The greater part of this amount has been secured during the year 1921. The State appropriated $300,000 to save some of the finest redwood groves along the State Highway in the basin of the south fork of the Eel River. Under the direction of the State Forestry Board the plan for saving groves with this appropriation has been completed. During the year the league itself has deeded to the State of California 263 acres of redwood land acquired with funds donated by its members. In addition the State has acquired title to pieces of redwood timber land previously purchased through appropriations by Humboldt County and donations from Hon. Wm. Kent and Hon. Stephen T. Mather. All of these pieces are located in the basin of the South Fork of the Eel River. The league, during the past year, has increased its membership to 4,105.

SOCIETY AFFAIRS

The Pennsylvania Section

The first meeting of the Pennsylvania Section of the Society of American Foresters was held at Harrisburg, March 10, 1922. Of the 39 members of the new Section, 29 were present, or an attendance of nearly 80 per cent. During the afternoon by-laws were adopted and the following program was carried out in full with brief discussions of each paper:

National Forestry in Pennsylvania, L. L. Bishop.

Some Special Planting Problems in Pennsylvania, Prof. Geo. S. Perry.

The Development of Wood Technology, Prof. G. R. Green.

An Effective Forest Fire Organization, Geo. H. Wirt.

Following a banquet a business and social meeting was held. It was decided to hold a stated meeting each year on the last Friday in February and a summer field meeting in July.

The meeting was addressed by Dr. J. T. Rothrock, honorary member, and Prof. H. H. Chapman, member of the New England section. J. S. Illick read an appreciation of Dr. Rothrock, calling attention to his long life of service to forestry in the country and especially in Pennsylvania, and expressing regret at the retirement of Dr. Rothrock from the Forestry Commission of Pennsylvania.

Resolutions protesting against the proposed transfer of the National Forests, in whole or in part, from the Department of Agriculture to the Department of Interior were adopted.

Section Officers for 1922

The sections named have elected the following officers for 1922:

Madison Section:

Chairman: T. R. Truax.
Secretary: E. P. Ancona, Forest Products Laboratory.

New York Section:

Chairman: R. S. Hosmer.
Secretary: O. M. Porter, 18 East 41st St., New York City.

Northern Rocky Mountain (Missoula) Section:

Chairman: T. C. Spaulding.
Secretary: S. V. Fullaway, Forest Service, Missoula, Mont.
Member of Executive Committee: Elers Koch.
Membership Committee: J. H. Ramskill, J. A. Larsen, G. I. Porter, C. N. Whitney, M. H. Wolff.

Southwestern Section:

Chairman: J. C. Kircher.
Vice-Chairman: H. G. Calkins.
Secretary-Treasurer: Quincy Randles, Forest Service, Albuquerque, N. M.

Pennsylvania Section:

Chairman: Gifford Pinchot.
Vice-Chairman: John Foley.
Secretary: John Ferguson, State College, Pa.

North Pacific Section:

Chairman: John D. Guthrie.
Secretary: A. J. Jaenicke, Forest Service, Portland, Oregon.
Member of Executive Committee: D. T. Mason.
Membership Committee: F. E. Ames, Hugo Winkenwerder, A. G. Jackson.
Program Committee (Meetings): J. S. Boyce, J. F. Kümmel, F. H. Brundage.

Washington Section:

Chairman: R. C. Hall.
Secretary: Rudolph Dieffenbach, Forest Service, Washington, D. C.
Member of Executive Committee: J. P. Kinney.

California Section:

Chairman: Swift Berry.
Secretary: Duncan Dunning, Ferry Building, San Francisco, Calif.

Southern Appalachian Section:

Chairman: J. S. Holmes.
Vice-Chairman: Verne Rhoades.
Secretary: C. F. Korstian, Box 1518, Asheville, N. C.

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